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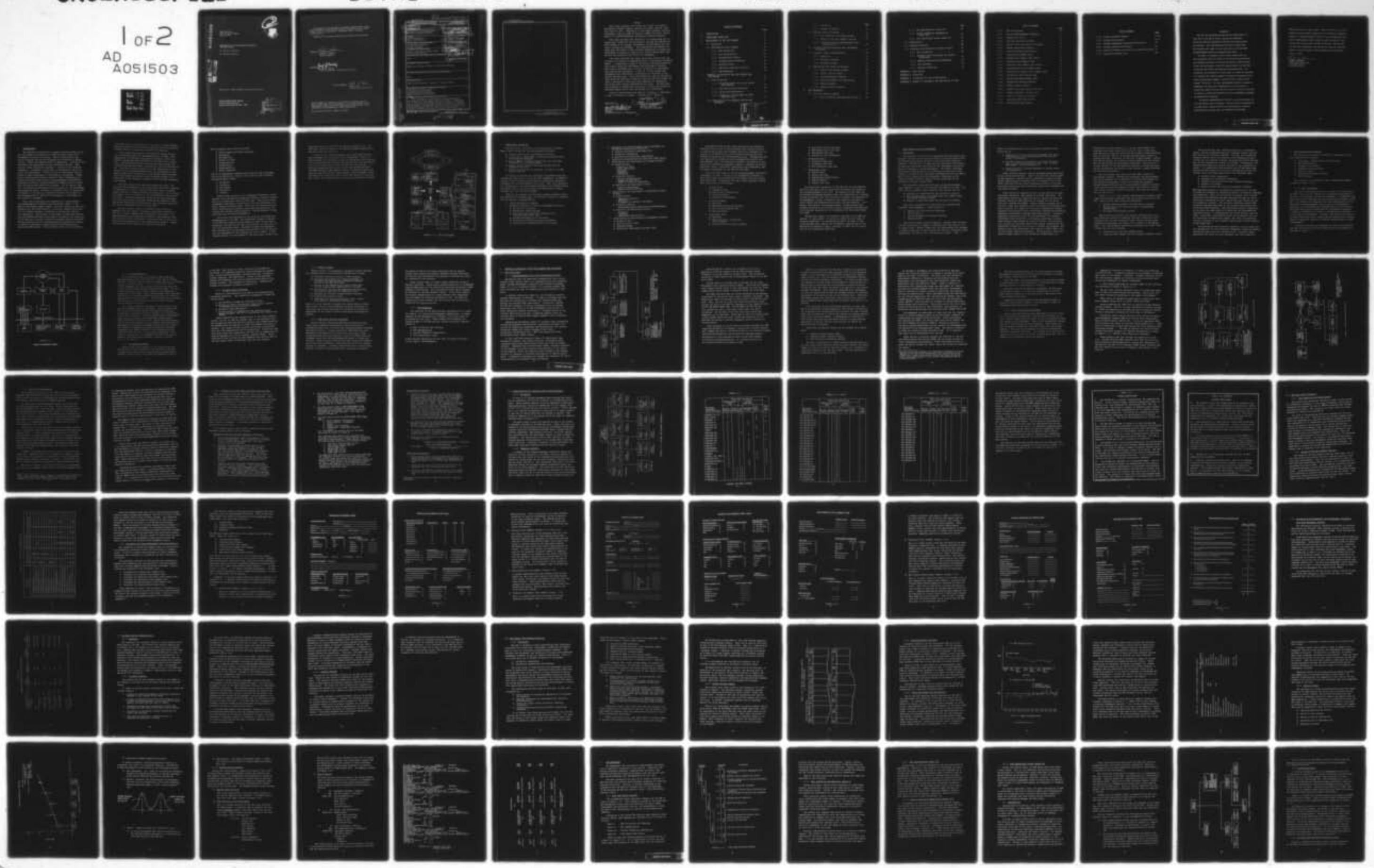

RADC-TR-77-419
Final Technical Report
January 1978

DEVELOPMENT OF SYSTEM/EQUIPMENT RELIABILITY CORPORATE MEMORY

Mr. James R. Wingfield

IIT Research Institute

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ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, New York 13441

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The feasibility of establishing a systems/equipment Reliability Corporate Memory (RCM) is studied. The purpose of an RCM is to continuously accumulate, compile, analyze and report reliability, maintainability and cost data on systems and equipment. Availability of these systems/equipments would ultimately improve with the identification and control of R&M sensitive parameters through all phases of development.

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PREFACE

This report presents the results of a study to develop a Reliability Corporate Memory covering the period June 29, 1976, thru June 30, 1977. Submission of this report fulfills the data requirement, CDRL No. A002 of Contract F30602-76-C-0370, "Development of a Systems/Equipment Reliability Corporate Memory".

The study addressed the feasibility of establishing and implementing a center for the acquisition, storage and analysis of data related to the design, development and performance of electronic systems and equipment. The organization and analysis of these data will permit a more accurate formulation of design and development strategies to improve the ultimate operational reliability and associated life cycle cost management.

The study indicated that these objectives could be met sufficiently to justify the implementation of a Reliability Corporate Memory. A significant volume of reliability and maintainability data exists along with development and procurement histories which can be accessed from a variety of sources by established data acquisition procedures. A list of 71 such systems and equipments were identified as candidates for inclusion in the initial RCM data base. The study defined the type of information which would be required to form the data base and this format was used to establish a trial data base comprised of information associated with systems identified by the study. The data base was automated to demonstrate the manner in which the Reliability Corporate Memory would store and manage this information.

Project contributions were made by R. Rebich, P. Mihalkanin, S. Kus, C. Proctor, N. Fuqua, I. Krulac, and L. Duvall.

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EVALUATION

RADC has long recognized the need for the establishment of a focal point in the DOD to collect, analyze and disseminate reliability data and information on existing and planned systems and equipment. This study addressed this need and established the foundation and format of such a focal point, called the RADC System/Equipment Reliability Corporate Memory (RCM).

The Memory is intended to serve military organizations and their contractors and will contain all the reliability-related data and information available on existing and planned systems including reliability requirements, reliability program emphasis and attitude, reliability test results and operational performance data. This information, when collected on a large number of systems and equipment, will represent the "lessons learned" on previous procurements and will assist system program managers in making decisions effecting their systems' reliability. The data, when properly collected, analyzed and summarized, will also help in determining the relative worth of reliability program activities and will be used by reliability analysts in refining, revising and developing reliability prediction, allocation and demonstration techniques.

The complete implementation of the RCM is an ambitious project and will take several years to complete. RADC has begun the implementation by establishing a separate Reliability Corporate Memory contractor-operated office and staff under the auspices of the existing

Reliability Analysis Center at RADC. Their first tasks will include establishing data contacts, computer files and marketing strategies. Hopefully, a sufficient amount of data will be collected during this initial implementation stage to enable the RCM to provide at least limited inquiry service and a saleable reliability data document. For additional information on the RCM and its status the interested reader is invited to contact either RADC/RBRD or the Reliability Analysis Center.

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1 INTRODUCTION

The reliability achieved by a complex military system in its use environment is influenced by numerous factors which occur throughout its entire life cycle. Some of these factors are purely technical and can be influenced and controlled by design actions. Others are administrative or managerial - related to the timeliness and organization of the reliability efforts. Some other of these factors are financial - related to the resources expended to accomplish a given level of reliability, and still others are operational - related to the use environment and the manner in which maintenance is performed and documented. Within these classifications reside a wealth of data, information and program decisions (from specific system/equipment procurements), impacting reliability and maintainability (R&M), which is invaluable for new systems acquisition programs. At the present time, this information is discarded at the conclusion of the development and production effort, retained in contractor files as proprietary information, or exists in a form which does not lend itself to easy dissemination to enhance the development or procurement of new systems or equipment.

This study investigates the feasibility of establishing a "System/Equipment Reliability Corporate Memory (RCM)" at the Rome Air Development Center (RADC), which can provide an effective mechanism for the identification, collection, analysis and retention of systems/equipment information including total R&M and cost experience. Functioning in this manner an RCM would provide data and information which could permit an analysis and comparison of the benefits of various reliability program control activities, and also provide data for refining prediction techniques leading to improved correlation between predicted-to-demonstrated-to-operational MTBF ratios. Other benefits accrue to the existence

of an RCM such as the provision of cost data to foster development and application of design and analysis tools for producing hardware with cost effective operational performance.

This study report presents the essential design features and a detailed plan for the implementation of the RCM. When implemented, the RCM will continuously identify, collect and analyze systems/equipment reliability and reliability related data. Included would be data starting with early design and extending through development, fabrication, test and operational use. The plan includes procedures for the identification and acquisition of systems/equipment data, the development of data summary forms and procedures for transcribing systems/equipment data into manageable automated data processing formats, considerations of the necessary document library and RCM management and staffing.

Two major aspects were addressed during the study. The first was the development of the users survey which was conducted to determine the needs of potential RCM users such as systems program officers, program managers and contractors, and to assess the general level of interest in the establishment and operation of an RCM. The second principal aspect of the study addressed the functional design of the RCM including the essential inputs and outputs which would be required for the successful operation of such an information analysis center (IAC).

The users survey, which is included in its entirety in Appendix A of this report, indicates a significant interest on the part of those companies and individuals interviewed. 363 questionnaires were distributed of which 71 (approximately 20%) were returned by the cutoff date. The return rate of 20% is considered to be indicative of a successful survey by mail. Twenty-five categories were studied for projected data needs.

Those categories most often cited were:

- Failure Modes and Effects Analysis
- Prediction
- MIL-HDBK-217B
- Failure Analysis
- R Demonstration
- Design Review
- Maintainability
- Design Trade-Off

63% of the respondents indicated that they are now collecting life cycle R&M and cost data in one or more of the following systems/equipment phases:

- Conceptual
- Validation
- Development
- Production
- Storage

Seventy-seven percent of all respondents expressed a direct interest in an RCM and were generally willing to provide information to an established center of this type. Fully 50% of these respondents indicated a utilization of all data categories on a daily, weekly or monthly basis. This level of interest was generally corroborated in personal interviews conducted with contractors and systems program officers. Further details of these interviews can be found in Appendix B.

The second area addressed by the study was the design and implementation of the RCM. Key operational elements essential to the RCM were identified and studied in terms of both their individual contribution and their relationship to each other in the total operating system. Candidate systems and equipments were reviewed and the techniques and procedures for the acquisition and management of the required data were studied. A flow diagram showing the relationship of the operational elements and

functional areas of the RCM is presented in Figure 3.1.1. As indicated, one key element is the ongoing systems identification and data collection activity.

A total of 71 systems/equipments were identified as potential candidates for inclusion in the initial RCM. Twenty of these systems were reviewed in depth by abstracting data relating to the various program elements and transcribing this information into sets of data summary forms designed for this purpose. A data base management system was studied and implemented using the RADC Honeywell 6180 computer system. Systems/equipment program data was entered into this automated data management system and selectively recovered demonstrating the ability of this system to meet the automated data processing requirements of an RCM.

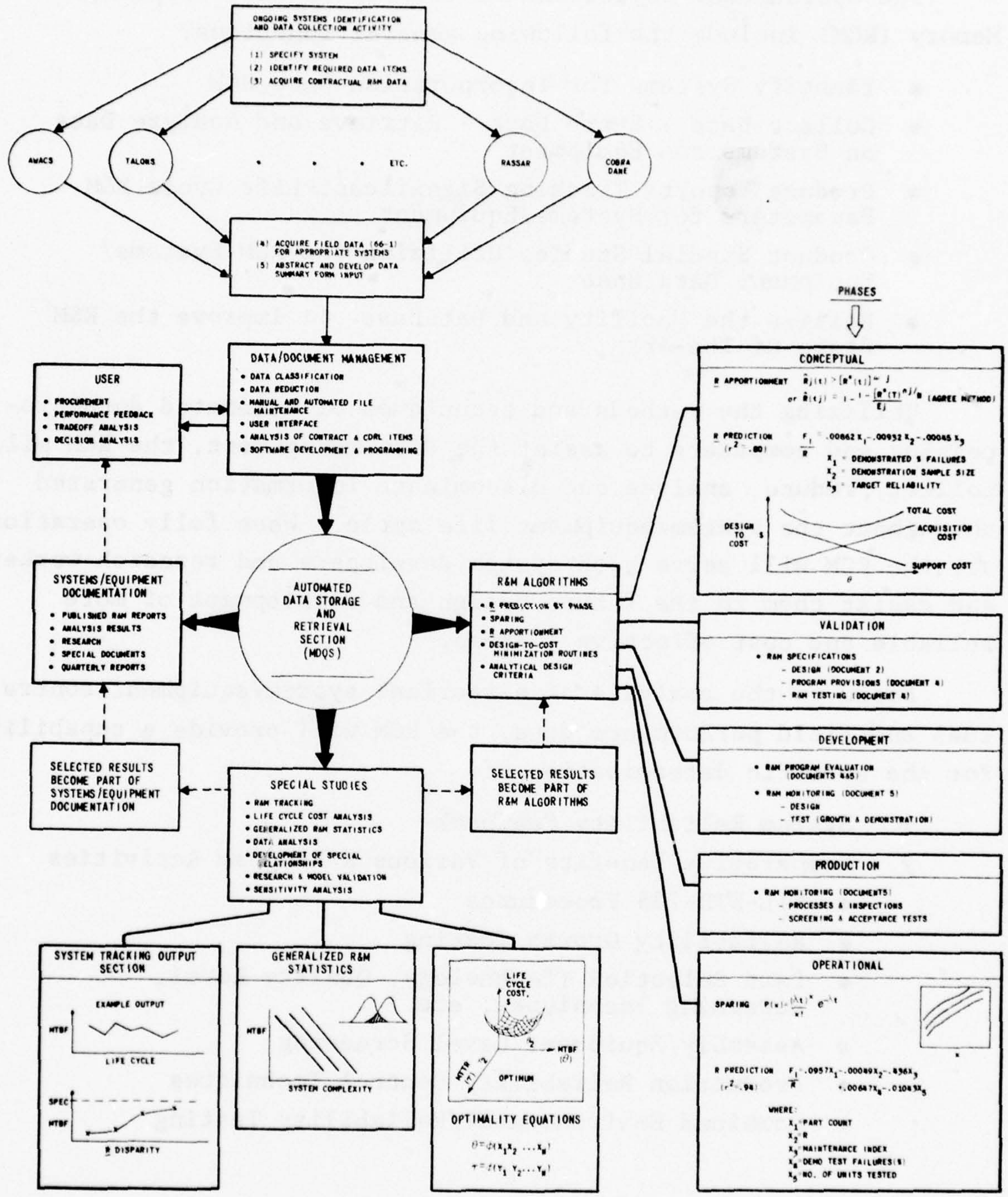

FIGURE 3.1-1 RCM FLOW DIAGRAM

2 OPERATIONAL OBJECTIVES

The operational objectives of the Reliability Corporate Memory (RCM) include the following general functions:

- Identify Systems for Incorporation Into RCM
- Collect Data - Store Data - Retrieve and Analyze Data on Systems and Equipment
- Produce Reports Tracking Significant Life Cycle R&M Parameters for Systems/Equipment
- Conduct Special Studies Utilizing the RCM Systems/ Equipment Data Base
- Utilize the Facility and Database to Improve the R&M State-Of-The-Art

Utilizing the methods and techniques of automated data processing and computers to assist the data management, the RCM will collect, reduce, analyze and disseminate information generated throughout the system/equipment life cycle. When fully operational, the RCM will serve both system developers and research workers and assist them in the future design and development of more reliable and cost effective systems.

Based on the analysis of historical system/equipment contractual and field performance data, the RCM will provide a capability for the specific determination of:

1. System Reliability Feedback
2. Comparative Benefits of Various R Program Activities
   - MIL-STD-785 Procedures
   - Reliability Growth Testing
   - Part Selection (Technology, Quality Level, Screening Techniques, etc.)
   - Assembly/Equipment Level Screening
   - Production Reliability Control Techniques
   - Combined Environmental/Reliability Testing

3. Techniques for the Development and/or Refinement of Reliability Modeling and Prediction
   - Inherent Reliability (MIL-HDBK-217B)
   - Production Degradation
   - Operation and Maintenance Degradation
4. Predicted-to-Demonstrated-to-Operational MTBF Ratios
5. Effectiveness and Improvement of R Design Concepts
   - Design Factors
     - Quality of Parts
     - Parts Application
     - Derating
     - Simplicity
     - Redundancy
   - Production Factors
     - Process Induced Defects
     - Inspection Efficiency
     - Number of Tests or Inspections
   - Operations and Maintenance Factors
     - Physical Environment
     - Human Initiated Failures
6. Effectiveness and Improvement of Maintenance Design Concepts
   - Design Factors
     - Diagnostic Features
     - Modularity
     - Alignment and Checkout Procedures
   - Production Factors
     - Workmanship Errors Requiring Field Maintenance
   - Operation and Maintenance Factors
     - Personnel
     - Logistics
     - Maintenance Organization
7. Effectiveness of New Acquisition Management Concepts
   - Design to Cost
   - Life Cycle Cost (LCC)
   - Balanced Design
   - Reliability Improvement Warranty (RIW)

Designing the RCM to meet these objectives has required a detailed consideration of the procedures and criteria involved in identifying systems and equipment which are candidates for inclusion in an RCM data base, the associated data sources and methods of obtaining the information described. Consideration has also been given to other key areas encompassing specific data requirements, data transcription procedures, utilization of computers and information management systems, a document and source materials library, analytical capabilities and requirements and the general management of the RCM and its staff.

Since the RCM intends to track systems/equipment reliability performance in time, a review of the information available at each major stage was performed and five major life cycle phases were identified. Examples of the type of data generated during each unique phase is as follows:

1. Concept Phase
   - Complexity Data
   - R&M and Cost Tradeoff Data
   - R&M Requirements
   - Compliance Requirements
2. Validation Phase
   - R&M Plans
   - R&M Review Points and Criteria
   - R&M and Cost Tradeoff Data
   - R&M Assessments
3. Development Phase
   - R&M Plans
   - R&M Allocations, Predictions and Assessments
   - Failure Modes and Effects Analysis

- Reliability Growth Test Data
- R&M Demonstration Test Data
- Nonstandard Part Data
- Acquisition Cost Assessments

4. Production Phase
- Production Test Data
- Acceptance Test Data
- Unit Production Cost Data

5. Operational Phase
- Failure Data
- Operational Data
- Engineering Change Proposals
- R&M Assessments
- Support Cost Data

The operational objectives of the RCM call for the identification of such data and its acquisition throughout all phases of the systems/equipment life cycle. An analysis of this data and the associated program elements permit the compilation of a lessons learned philosophy which will be used to increase the awareness of the management, design, reliability and logistics personnel to those factors and program policies which are R&M sensitive. As a result, deficiencies in program planning, program control and hardware reliability will be more readily recognized and direction for corrective measures will be strengthened by the establishment of an RCM.

During early stages, the resources available to the RCM will inhibit, to some extent, its ability to offer the full range of services envisioned. By concentrating effort in areas of data voids and high user interest the operational capabilities of the RCM would be expected to grow, therefore, to meet the full potential of its operational objectives.

3 RELATIONSHIP OF KEY RCM ELEMENTS

3.1 Discussion

The necessity and value of an automated data processing capability is related to the type and volume of the data being collected and the applications to which a data base thus formed are directed. The RCM will be based upon the continuous assimilation of data and information pertaining to the development and performance of hundreds of systems/equipments. The timely reportage, analysis and interpretation of a large mass of data thus represented by the RCM can be reasonably considered only by the employment of such computerized data management techniques as are currently being routinely applied to part level data by the Reliability Analysis Center (RAC).

The automated storage and retrieval of systems/equipment level R&M data is one of the essential functions of the RCM. The basic activity elements which comprise this function are the:

- Ongoing data identification and collection activity.
- Data interpretation and translation into summary forms and machine readable records.
- Computer system maintenance and software development.

Four basic categories of output form the envisioned RCM automated data management. These consist of:

1. General Data Retrieval and Reportage
2. R&M Statistics
3. Systems/Equipment Performance Tracking
4. R&M Algorithms

The first of these output categories - general data retrieval - will be structured in a manner to organize and print data on file in report forms. Report formats will be predetermined and designed to organize the type of data printed into the most informative mode depending on the objective of the particular report. Thus, a

family of standard reports can be generated addressing such objectives as:

- Complete list of all systems and equipment for which performance of the systems/equipment function and stage of development.
- Specific reports on categories of systems and equipment including R&M performance data, cost, program development, and contractual data.
- Classification of systems/equipment by failure modes and frequencies.

These, and other reports, will be standard output with information updated periodically. Other, more specific reports based on data analysis, research topics, hypothesis testing or other similar RCM associated interests will be produced on an ad hoc basis requiring both the report generating ability of the data retrieval section and those analytical capabilities designed into the system software.

These analytical capabilities will be provided by two other functional categories, R&M statistics and R&M algorithms. The generalized statistical capability will be similar to those subroutines offered by SPSS (Statistical Package for the Social Sciences), STATPAC and BIOMED. Simple computer programs can be written to make data available from the extensively developed data base to any one of a number of statistical computation routines. Frequency distributions may be analytically defined and population parameters determined by maximum likelihood methods. Population hypothesis testing and curve fitting techniques will provide researchers with the ability to determine significant relationships between large numbers of system variables, develop predictive reliability functions which relate design, demonstrated and operational reliability for classes of systems and equipment and optimize life cycle performance with respect to MTBF, MTTR, cost and procurement approach strategies. The statistical capability would be under control of the reliability professional as a

research and decision making tool. As new relationships are developed and tested using the accumulated data, those which find persistant usage and value will be included in R&M algorithms. This section will consist of working functions which assist in systems modeling, prediction by function, R apportionment, sparing and similar aspects of reliability design required in the development of new designs and procurement approaches. RCM users will be kept abreast of the RCM algorithm capability through published reports documenting the results of any research, example problems and special applications.

The last primary area fed by the data bank consists of performance tracking. Through this mechanism, systems/equipment LCC and performance can be related to the functional history of both specific and generic classes of systems and equipment. Systems Program Officers can visualize graphic displays relating actual and predicted performance, monitor the effects of corrective actions and make informed decisions concerning the development of new systems.

Figure 3.1-1 is a flow diagram indicating the principal input/output relationships associated with the automated portion of the RCM. Three initial input steps are identified.

1. Specify system/equipment for which data is desired.
2. Specify data to be collected and/or corresponding documentation.
3. Determine data/document sources.

These activities would be the logical responsibility of the Data Collection portion of Technical Services, which would also interface with the data document storage library function under Information Processing (see Figure 5.2-1, Section 5, RCM Management). The data/document inprocessing continues with Steps 4 and 5 which call for the following:

4. Transcribe data into Data Summary Forms.
5. Translate Data Summary Form into machine readable records.

Once the data has been coded and stored in a retrievable manner, queries requesting specially organized outputs from the data base can be routinely executed. At least one reliability engineer familiar with both statistics and computerized applications will be required to direct and guide the overall development of the computational outputs of the RCM. Conceptually, the computational capability is most required in two categories of output: (1) generalized R&M statistics and (2) R&M algorithms. Generalized R&M statistics covers the availability of most statistical tools including those used in the following areas:

- multiple linear regression
- estimation of statistical parameters
- frequency distribution and curve fitting techniques
- analysis of variance
- quality control and acceptance sampling techniques

R&M algorithms pertain to the analytical capability of the RCM. Included are mathematical techniques common to reliability modeling and prediction. While not statistical in nature, many of these analytical relationships have been developed through the use of statistical techniques and their application may require the use of probability concepts. The principal difference between R&M statistics and R&M algorithms is the research orientation associated with R&M statistics. R&M algorithms provide a capability, the accuracy and applicability of which has been developed and rigorously tested. A communication does exist between these two areas. Functional relationships which are developed by the use of statistical techniques may suggest that their use qualifies them for inclusion in the standard computational routines defined as R&M algorithms.

The generalized data retrieval capability is an accepted and well defined part of any information management system and permits specialized data sorts and classifications. Automatic report generating activities are also dependent upon this capability.

3.2 RCM Organizational Elements

The functional operation of the RCM is comprised of seven basic organizational elements:

1. Data Source Identification and Collection
2. Data Transcription
3. Document Data Library
4. Automated Data Processing
5. Special Studies
6. RCM Output and User Interface
7. RCM Management

The schematic relationship of these organization elements is shown in Figure 3.2-1.

3.2.1 Data Collection

The data collection activity is critical to the function of the RCM. This activity consists of a continuous monitoring of the status of candidate systems and equipment. Any R&M data item associated with a candidate system is potentially valuable to the RCM. Its assimilation requires first the identification of the associated systems/equipment and its source of availability. Initially, the identification of systems and the collection of data will require both prospective and retrospective searches. A system or equipment of interest to the RCM may be deployed, or in any stage of development. Multiple data sources can exist for any given system and these sources may be protected by a manufacturer's proprietary interests, security considerations or other entanglements.

Procedures defining the mechanism of system identification and data acquisition have been formulated and are presented in Sections 4.1 and 4.2.

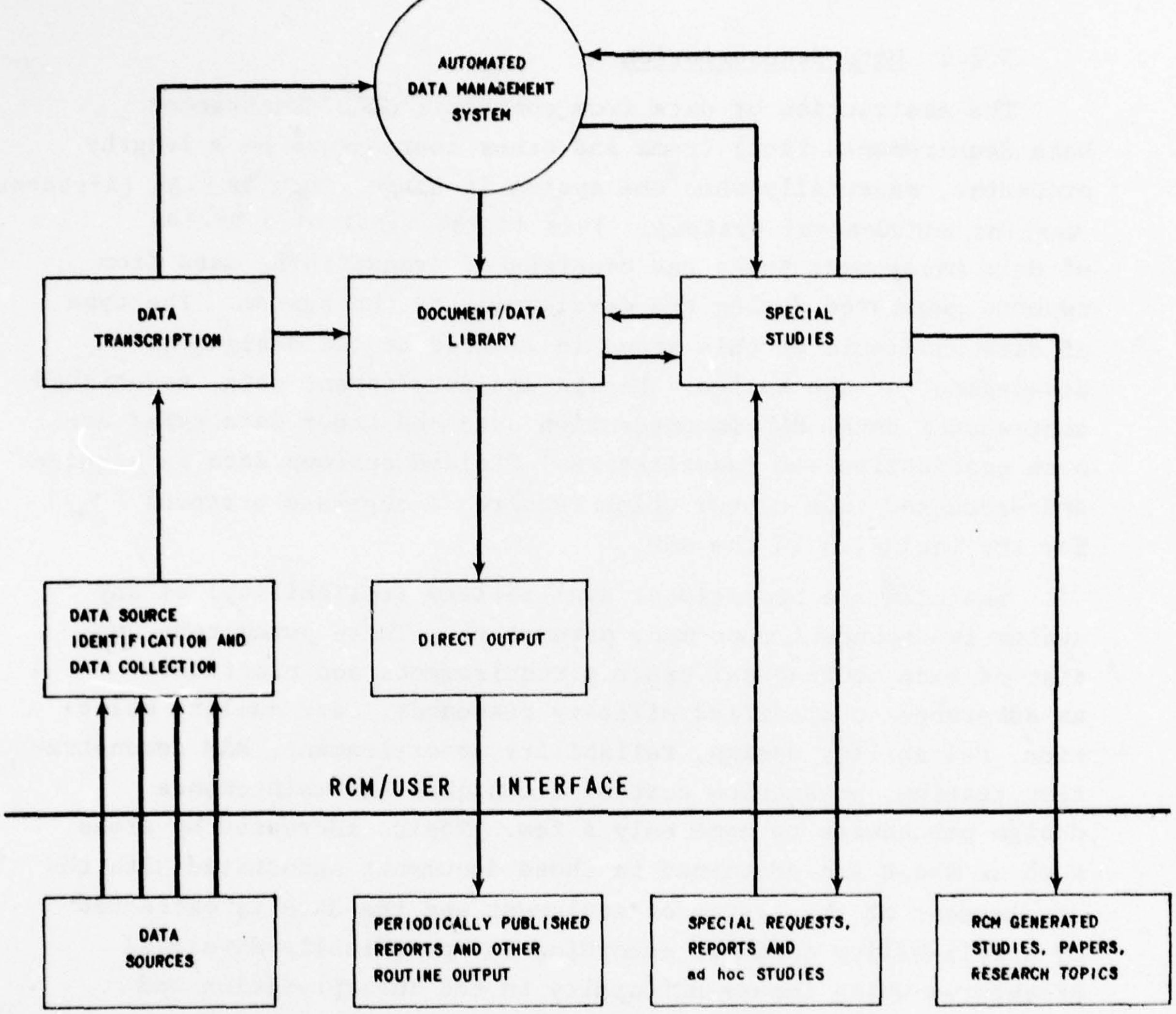

FIGURE 3.2-1

GENERAL RCM MANAGEMENT SCHEMATIC

3.2.2 Data Transcription

The abstraction of data from contracts CDRL (Contractor Data Requirements List) items and other sources can be a lengthy procedure, especially when the system is large, such as F-3A (Airborne Warning and Control System). This is the first of a series of data management tasks and consists of transcribing data from reports generated during the development of the system. The type of data available at this stage is limited to the design and development of the system. Design and development data, associated contractual data, R&M demonstration data and other data types are both qualitative and quantitative. Fielded systems data is acquired and processed in a manner which requires a separate protocol for its inclusion in the RCM.

The ultimate operational availability (reliability) of any system is dependent upon many parameters. These parameters consist of such contractual program requirements and practices as adherence to specified military standards, part quality selection, reliability design, reliability apportionment, R&M demonstration testing, production control techniques and maintenance design procedures to name only a few. Topics addressed by areas such as these are contained in those documents associated with the development of the system or equipment and the data is extracted by a reliability engineer according to specifically developed procedures which insure uniformity in the interpretation and transcription of the data. The information abstracted in this manner is transferred to Data Summary Forms which have been prepared for this task and are discussed in detail in Sections 4.3.1, 4.3.2, and 4.3.3.

3.2.3 Document/Data Library

Physical space and procedures for the classification and storage of hard copy is essential to the operation of the RCM. A document/data library will provide logistical organization to documents associated with the systems and equipment of interest

to the RCM. Easy access to these items will be provided by cataloging and indexing techniques cross-referenced by document type, related systems/equipment, systems functions, contractor, systems component, and application. Copies of RCM generated reports and documents will also be classified and stored in the Document Library. The mechanics of cataloging, indexing and storage are discussed in detail in Section 4.5.

3.2.4 Automated Data Processing

Central to the functions of the RCM is the Automated Data Processing capability. This capability encompasses a number of related areas:

- The automated storage and retrieval of data.
- Ability to compile and execute computational routines in mathematical and statistical analysis.
- Automatic report generation.
- The generation of commands for the control of peripheral equipment such as X-Y plotters and CRT display terminals.

These capabilities are generally part of any large computer system, such as the IBM 360, UNIVAC 1108, or the Honeywell 6180. The storage and retrieval function requires that communication be established with the compiler in order for program executions to proceed. The content of each logical record must be specified such that data manipulation may be accomplished. Toward this end, Data Entry Forms were designed as the next step in organizing the Systems/Equipment data into a machine readable format. These forms are filled out from the Data Summary Forms and are used by the data entry clerks to keystroke data into the computer.

3.2.5 Special Studies

Special Studies is principally a research oriented function. The responsibilities associated with the RCM area include:

- Providing technical services to RCM clientele.
- Assisting and working with system programmers to establish the computational capability required for exercising R&M algorithms.
- Setting up the communication between input data and the computational capabilities of the RCM.
- Verifying the accuracy of computation by exercising the routines with data and sample problems.
- Updating the library of computational routines.
- Establishing research topics.
- Developing and applying analytical tools; statistical analysis, hypothesis testing, etc.

While it is not possible to predict the total output or effect which issues from the broad technical activity envisioned in this area, the guiding philosophy is one which anticipates an advancement in the state-of-the-art prediction and analytical methods.

3.2.6 RCM Output and User Interface

Output from the operational RCM can be generalized into three basic categories consisting of tabular print-out of systems/equipment data in report form, systems/equipment tracking, and special studies. Tabular print-outs identified for early demonstrational purposes will include an echo print of the unstructured RCM data base contents, gross level MTBF values by equipment class and also maintainability output to inform contractors, systems program officers and other interested individuals of the basic performance trends associated with the subject systems or equipment. A highly specialized form of output would consist of special studies which have a research orientation.

The specific form of the output resulting from the special studies would require preliminary agreement between RCM personnel and the user clientele for the purpose of defining the specific character of the analysis.

These various kinds of output require different levels of RCM/user interface. Those output products which are of recognized ongoing importance will be refined and generated periodically with automatic distribution. This distribution level may be handled by personnel in the RCM document library. Still other requests may require communication on a more personal level suggesting the involvement of technical personnel at RCM. All means of communication media between the user and the RAC will be incorporated by the operational RCM.

3.2.7 RCM Management

All functions of the RCM previously mentioned will be under the control of a centralized management organization. A staged schedule of RCM implementation covering a five year period is envisioned by this study. These stages will encompass the logical growth of the RCM and will include such basic considerations as:

- Data collection and reduction
- RCM implementation
- Service capability augmentation
- Full operational status

A more detailed discussion of this topic is found in Section 5 of this report, RCM Management.

4 TECHNICAL DISCUSSION OF KEY RCM ELEMENTS AND ACTIVITIES

4.1 Data Collection

4.1.1 System/Equipment Life Cycle Phases/Data Sources

Reliability data and supporting documentation from a given program covers several years as it progresses from the conceptual stage, through development, production and eventual deployment. Figure 4.1-1 is a conceptual diagram of a typical program life cycle and shows the type of documentation/data produced at each phase.

At Contract Definition (Phase I), the reliability control program requirements are defined. It might be presumed that the RCM would be interested in tracking only systems having well defined and specified R&M requirements. In practice, however, the RCM must attempt to build an information file on programs which have very little or no R&M development plans as well as those having well defined requirements. Programs devoid of significant R&M activity provide a background against which the relative merit of certain R&M program judgments can be reflected and evaluated.

Engineering Development (Phase II) produces basic information concerning equipment specifications, application stresses, etc., as well as reliability prediction and demonstration test reports. Production (Phase III) yields Equipment Level Tests, Reliability Verification Tests (RVT) and Corrective Action Verification Tests (CAVT) reports.

At Test and Field Operation (Phase IV) operational logs, malfunction reports, and technical manuals (illustrated parts breakdown identifying nomenclatured items) are items of primary interest. Operation Test and Evaluation (OT&E), warranty contracts or LCC programs all produce reports characteristic of the nature of the program. After the system has been fielded it may undergo retrofit or redesign to alleviate deficiencies or improve performance. Information concerning such changes are necessary for valid interpretation of subsequent field performance.

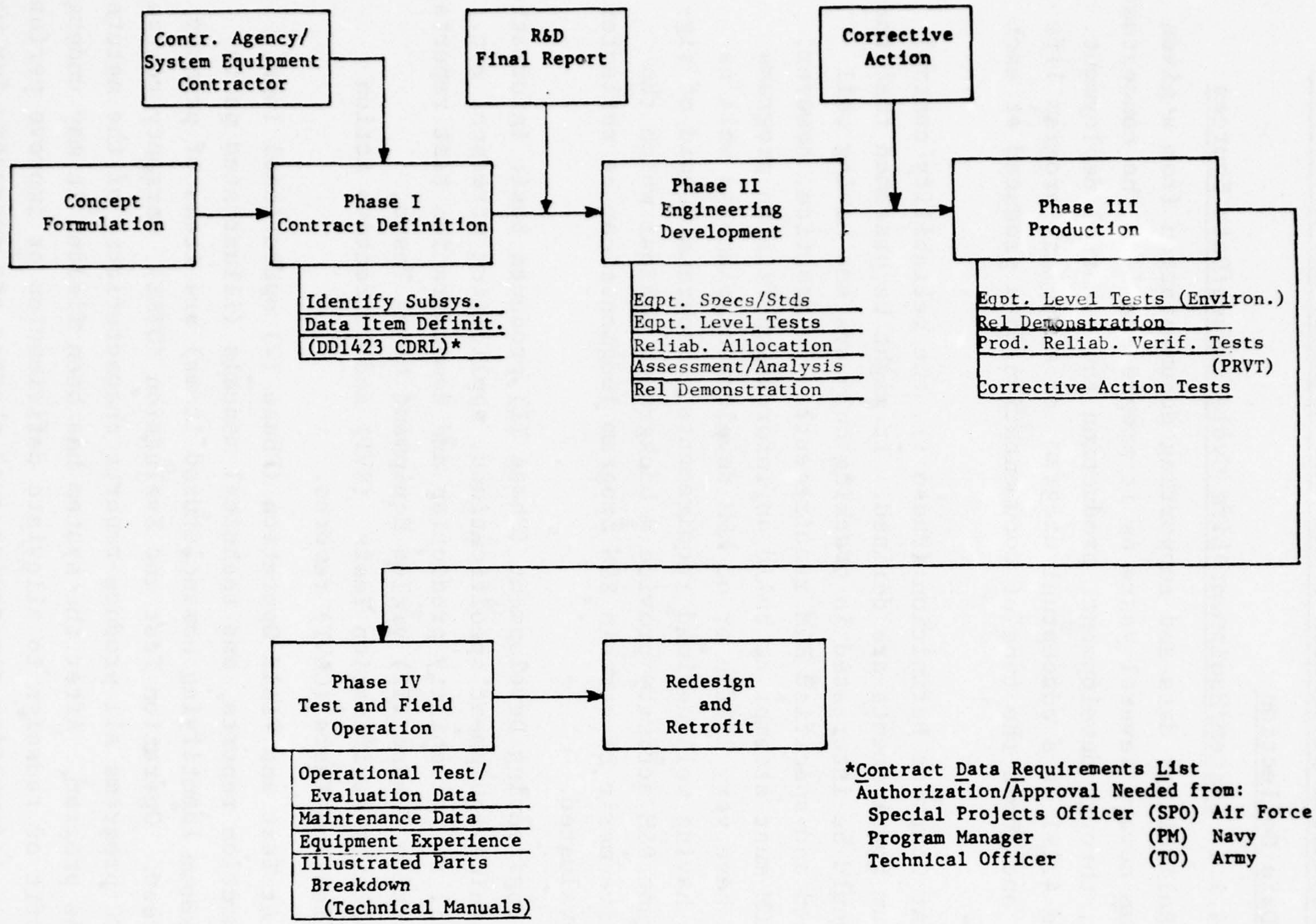

Figure 4.1-1 Program Life Cycle

Selected AFM 66-1 reports are available to Air Force Agencies on official request from the D056 program called "Forwards" or Log mm (formerly called K Log). The information contained in these reports are in predesigned formats to fit the users needs.

Another source of systems data is through the Air Force Maintenance Data Collection System (MDCS). Data from the Command Level Inquiry System (CLIS) is also obtainable from the Air Force Communication System (AFCS) at Richards Gebaur Air Force Base.

The MDCS data describes the action performed by maintenance technicians at various Air Force bases throughout the world. The malfunction codes are the same as those used in the AFM 66-1 program. Thus, the user can trace the repair/maintenance action through the CLIS to the AFM 66-1 equipment or part repair by the use of a job control number (JCN). The JCN remains the same from the line through the shop to the depot repair where the JCN is terminated. At the base level other data such as End Item Summaries can be retrieved. These data as well as the Base Level Inquiry System (BLIS) and CLIS, yield some indication of the downtime and uptime of specific equipment during a monthly reporting period.

Other programs in the Air Force now being developed are IROS (Improved Reliability of Systems), dealing with costing tradeoff data, RAMFAS (Reliability and Maintainability for Airborne Systems) dealing with maintainability, and the Reliability Improvement Warranty Data Base which is being developed to obtain the data being assembled on Reliability Improvement Warranties. It is expected that data from all of these activities can be acquired by RCM.

While it is important for the RCM to identify and establish an early interface with systems programs still in the conceptual stages, the establishment of an RCM will automatically define a point-of-entry into the past-present-future development and generation of systems/equipment information. For those systems which are already in various stages of development a retrospective program of data accumulation will be necessary to build an active historical data base which can begin to be applied to near future systems development. This study has addressed this requirement in terms of identifying systems and equipment which are desirable candidates for inclusion in the inital RCM data base. Previously developed systems were identified, data collected and used in a pilot automated data processing plan defined by the objectives of the RCM.

With exception of the surveillance necessary to alert the RCM of an impending systems program the data sources utilized for the accumulation of retrospective data are much the same as those which will be expected to provide data during the ongoing development of new systems/equipment. A methodology was defined for this study using regularly published official or quasi-official government listing of contract solicitations and awards for identification of programs.

Three major information sources can be reviewed on a regular basis:

1. Commerce Business Daily (CBD)
2. Electronic News (Contract Awards)
3. DDC (Work Unit Information System)

The CBD is desirable as it makes possible identification at an early point those contracts which are being awarded, and should enable the RCM to be written into the contract as a recipient of selected reliability and test data items. The RAC regularly accomplishes this on a routine basis.

As systems or equipments are being produced or deployed, samples are taken and subjected to extensive testing by Air Force agencies and their contractors. Two basic test and evaluation requirements (AFR-80-14, "Research and Development Test and Evaluation") are Developmental Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E). DT&E is conducted to demonstrate that engineering design and development are complete and that the system/equipment meets the specified requirements. OT&E is conducted to assess a system's operational deficiencies and need for modification. Tests performed during the OT&E period are the Initial Operational Test and Evaluation (IOT&E), AFR-23-36, "Organization and Mission Field, Air Force Test and Evaluation Center (AFTEC)", which provides an estimate of system operational effectiveness and suitability. These tests end at the first major production decision and are then considered, when extended, to become Follow-on Operational Test and Evaluation (FOT&E) AFR-23-36.

The management or monitoring of these tests are the responsibility of selected members/teams of Air Force Major Commands for organization and mission-field activities. These subsections are requested by AFTEC, Air Force Flight Test Center (AFFTC) and Air Force Weapons Test Center (AFWTC). Extensive long-term testing on ground systems/sets and the results and recommendations are reported by the aforementioned teams. The reports submitted by AFTEC are currently being obtained by RAC. It is expected that these can be incorporated into the RCM.

AFTEC results on airborne systems are submitted to the Systems Effectiveness Data System (SEDS) and are being recorded as "Line" maintenance action/repairs, "Shop" maintenance action repairs and lastly through the "Depot" where the contractor completes the repair.*

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*Two Air Force data systems, The Maintenance Management Program (AFM 66-1) and the Fleet Maintenance Data Collection System (AFM65-110), report maintenance actions performed during the field operational phase--at all levels from Airborne System to Sets to Parts.

The data generated during all of these periods of systems development and operational testing can be accessed and brought into logical organization by the RCM.

While the RCM is concerned primarily with Air Force Systems at the present time, the availability of operating data on Army and Navy systems is nevertheless of interest.

The Navy utilizes the Material, Management and Maintainability (3M) Program. It is not as sophisticated as the Air Force AFM 66-1 system as it allows access to data only to the lowest nomenclatured level.

Supporting technical manuals defining design changes or retrofits and operating manuals can be obtained in order to determine engineering design criteria.

4.1.2 Data Solicitation Procedures

Once a system-program has been identified the first action is to establish the appropriate contacts and determine the extent to which required data has been or will be generated during the course of the development. This can be accomplished through the use of form letters and questionnaires. These forms are sent to specific recipients identified within the contracting agencies. The form would accompany the initial solicitation letter for programs identified. Its purpose is to obtain information on the status and the nature of reliability data that is expected to be produced during the contract.

Aggressive follow-up is essential to assure the obtaining of selected data. Frequently preparation and shipment of promised data items are pre-empted. Therefore, a formal collection record for each program, logging all contacts, delivery promises and actual data submission is highly recommended.

A flow diagram depicting the various stages of the solicitation procedure is shown in Figure 4.1-2.

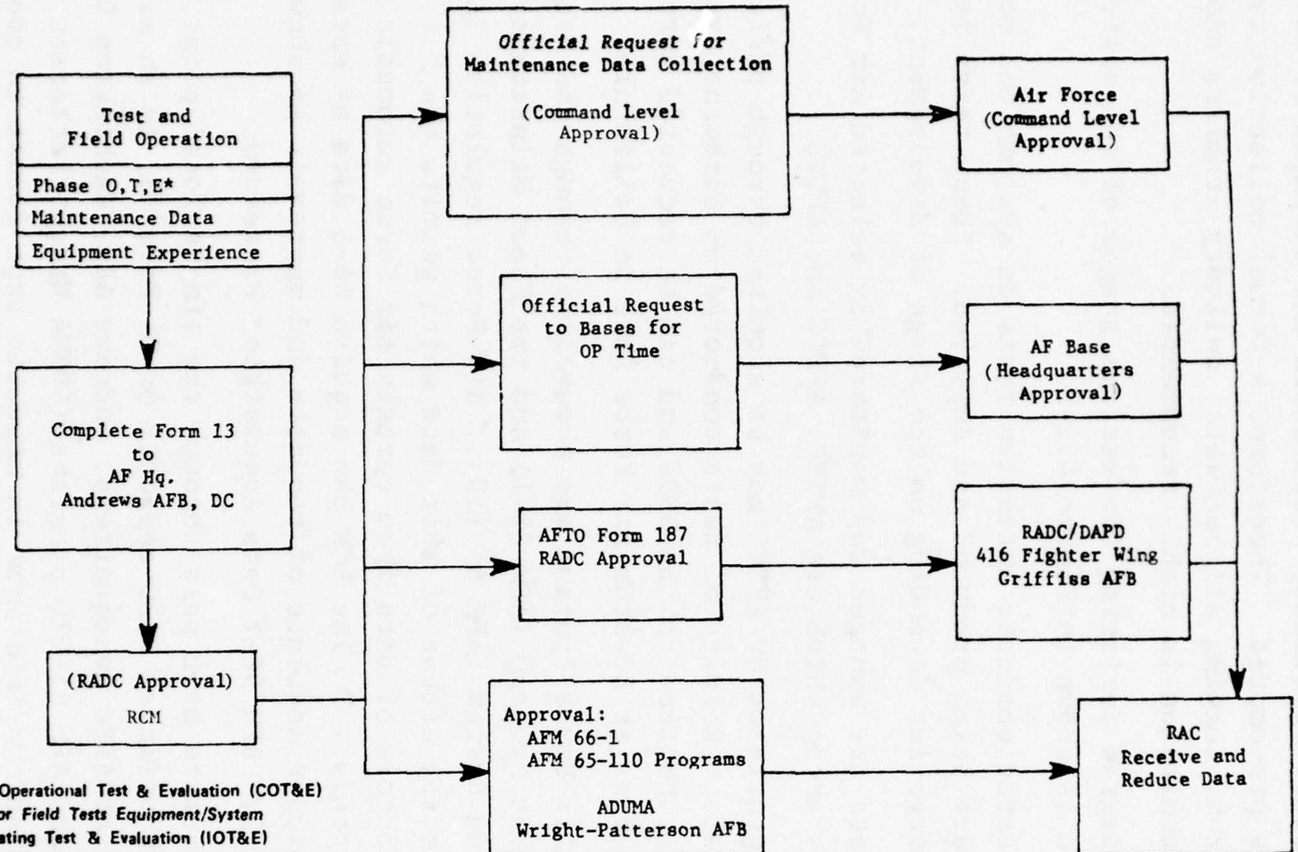
The Air Force conducts extensive tests on systems and equipment as they are being produced and deployed. These tests fall into three categories depending on the stage of development.

These tests are managed and monitored by selected Air Force Major Commands among which are AFTEC, AFFTC and AFTWC.

Reports generated by AFTEC may be acquired through official request channels. Results of tests conducted on airborne systems by AFTEC are submitted to the SEDS and can be requested through official resources at Edwards Air Force Base in California.

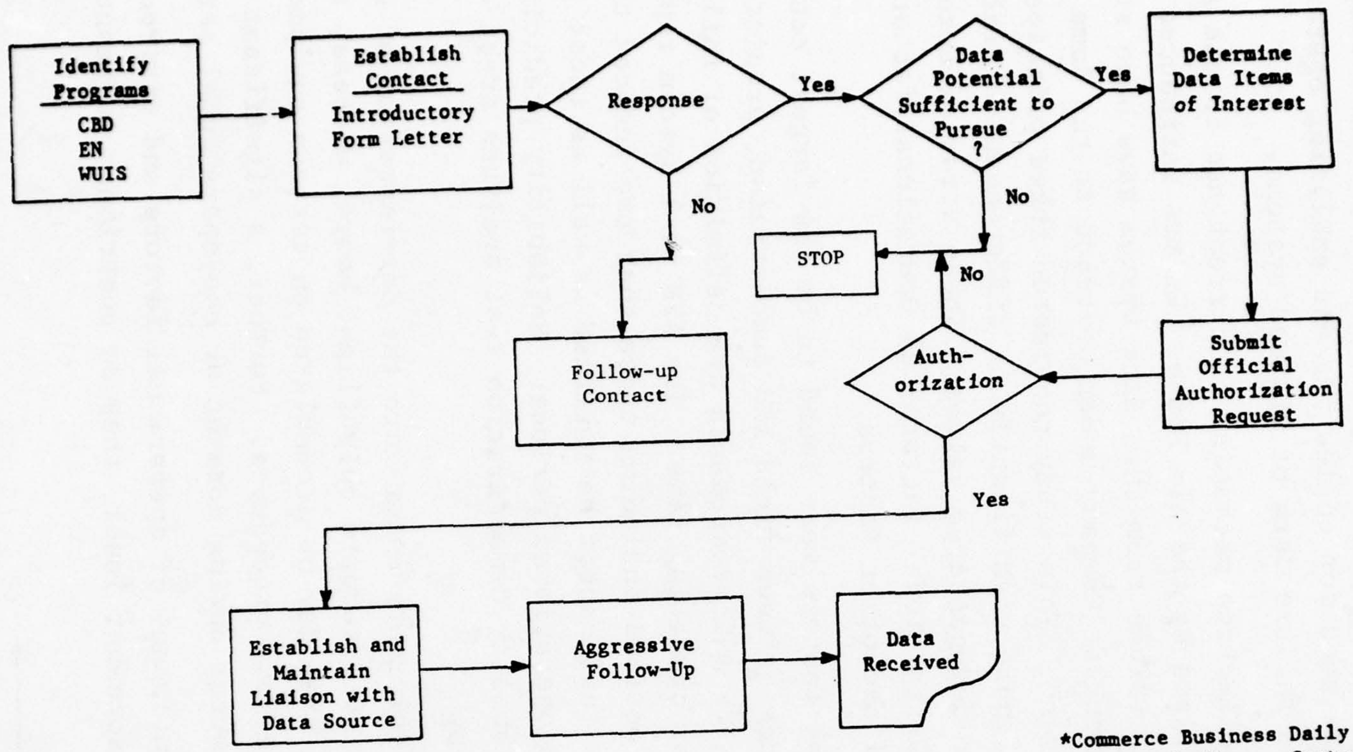
Fielded Air Force systems are accessible through the Maintenance Management Program (AFM 66-1) and the Fleet Maintenance Data Collection System (AFM 65-110). Air Force regulation (AFR 178-6) governs the access of this data which permits the "...feedback to contractors of data from certain Air Force automatic data processing systems..." The RCM can acquire 66-1 data by establishing the proper sequence of requests and approvals as shown in Figure 4.1-3, AFM 66-1 Data Acquisition Procedure.

These requests must pass through the single focal point, (e.g., through official RADC approval on DD Form 13) to an Air Force Liaison at AFSC Headquarters, Andrews AFB, Washington D.C. The AFM 66-1 and AFM 65-110 programs (ADUMA Wright Patterson AFB, OH) will furnish raw data only in magnetic tape format to contractors.



*Contractor Operational Test & Evaluation (COT&E)
Contractor Field Tests Equipment/System
Initial Operating Test & Evaluation (IOT&E)
Contractor/Customer Field Tests Equipment/System
Follow-on Operational Test & Evaluation (FOT&E)
Customer only Field Tests Equipment/System

Figure 4.1-2 Data Solicitation Procedure



*Commerce Business Daily
Electronic News - Contract Awards
DDC - Work Unit Information Summaries

Figure 4.1-3 AFM 66-1 Data Acquisition Procedure

4.1.3 Field Data Requirements

The fundamental objective of the RCM to track system/equipment R&M experience through the total life cycle automatically defines the need for collecting and analyzing operational, maintenance, and failure data of fielded systems.

One data collection mechanism in current use is the AFM 66-1 system utilized by the Air Force. Errors introduced in calculating MTBF values from this data system have been studied by the Hughes Aircraft Company under contract to the Rome Air Development Center[1]. This study considered three principal factors which contribute significantly to differences in field MTBF and predicted or demonstrated values. These error effects result from: 1) Definitional factors; 2) Operational factors; 3) Environmental and other factors.

Definitional factors were found to be the largest contributor to differences between field and demonstrated, predicted and required MTBF. Its main components are definition of failure and definition of operating time. The AFM 66-1 system reports all maintenance actions including those that are induced through misuse and those that cannot be verified as well as those that occur during non-operational periods. Reliability prediction methods and reliability demonstration test analyses treat only relevant failures.

A number of elements enter into the determination of operating time. AFM 66-1 reports only flight hours, whereas, appreciable operating time may be accumulated on certain equipments during ground checkout procedures. Further, a significant number of failures occur during dormant or non-operational periods.

While the influence of operational factors and environmental factors are somewhat lower, they do contribute substantially

[1] Kern, G.A., and Drnas, T.M., "Operational Influence on Reliability", Hughes Aircraft Company, RADC-TR-76-366, Contract No. F30602-74-C-0221, Final Technical Report of December, 1976.

to differences between field and predicted or demonstrated MTBF values. Operational factors include maintenance handling (% removals and % shop repairs) and equipment use (mission duration, utilization rate and operating to non-operating time ratio). Environmental factors cover undefined differences in operating environments between individual system units of the same type and differences between actual operating conditions and levels employed during test or assumed in making predictions. The AFM 66-1 collection system cannot be charged directly with errors introduced by operational and environmental factors except by omission since it does not record data to this level of detail.

The Hughes study concluded that despite the misgivings relative to AFM 66-1 data, meaningful field MTBF values can be derived using this data base. We concur in this conclusion and suggest that -- with due consideration for potential error sources and motivated study -- the AFM 66-1 MDC system can serve both its intended functions as a base level maintenance management system and also as an appropriate vehicle for the estimation and evaluation of field system/equipment reliability parameters by the RCM.

Rather than accept the AFM 66-1 figures for flight hours, it is planned that the RCM access quarterly operational logs for each equipment of interest directly from the operating commands. With the operational profile, it will be possible to estimate, with some degree of accuracy, not only equipment mission operating time but also checkout time and dormant (non-operating) time. Where appropriate, each time factor can be entered into the RCM data base as a separate data element offering maximum analysis flexibility.

Malfunctions will be classified according to where they were observed and their effect on system/equipment operation. This classification will enable independent computation of logistic MTBF values (all malfunctions) and functional MTBF values. It is planned that close liaison will be maintained with repair depots to resolve interpretation problems as they arise.

4.1.4 Estimation of Field MTBF and MTTR From 66-1 Data

Data available through the AFM 66-1 system was used in an exercise to estimate such R&M numerics as MTBF and MTTR. This exercise was performed primarily in order to review our experience with the basic mechanics of the system and demonstrate its use in the computational aspects associated with operational and field data. While no attempt was made at this stage to observe the cautions indicated in the previous section, the ultimate utilization of this data source will fully consider the errors which are induced by definitional and operational factors. These preliminary estimates of MTBF and MTTR first required the selective identification and retrieval of the data associated with a specific equipment. A decoding operation is required to obtain this data for use.

The procedure used in this study to obtain R&M data on one candidate system (TSC-60) was as follows:

Equipment Selection and Data Reduction Procedure

1. For Ground Equipments only "Off Equipment" failure records will be used. These records are identified by an "H" CARD CODE in column 80. All other records are to be excluded.
2. Identify the equipment for which data is to be obtained. This is identified by the Standard Reporting Designator (SRD) in columns 31 thru 33. The correct SRD for the applicable equipment will be found in manual T.0.00-20-2, "Air Force Maintenance Data Collection System". All records with an SRD other than the appropriate one, are to be excluded. For example: the applicable SRD for the TSC-60(V)1 Communications Central would be 8LG.
3. Identify the base locations for which equipment operating time is available. (This would normally be the result of an independent data collection effort). The BASE CODE is identified in columns 60 thru 63. A base code cross reference is to be found in Air Force Manual AFM 300-4, "Data Elements and Codes". All records with base codes other than those of the selected locations would be excluded.

4. All data entries with TYPE HOW MALFUNCTION CODE other than "1", indicating an actual failure, are considered to be non-relevant and are to be excluded. The location of this field is dependent upon the date of the data tabulation. Prior to July 1975 it was found in column 84, subsequent to this date it is found in column 81.

5. All data entries with a TYPE MAINTENANCE CODE other than "B", Unscheduled Adjustment, or "H", Emergency On-Site Repair, are to be considered non-relevant and are excluded. This code is found in column 30.

6. All data entries with an ACTION TAKEN CODE other than:
   - A - Bench Checked and Repaired
   - 9 - Bench Checked - Condemned
   - F - Repair
   - G - Repair and/or Replace
   - K - Calibrated - Adjustment Required
   - L - Adjust

   are considered non-relevant and are excluded. This code is found in column 44.

7. The remaining data entries are considered the relevant field failures recorded against the equipment under consideration. These entries should now be fully decoded including the following fields:

   a. Work Unit Code (columns 39-43)
   b. Job Control Number (69-71)
   c. Record YEAR (34)
   d. Record DAY (35-37)
   e. START TIME (51-54)
   f. STOP TIME (55-58)

   The WORK UNIT CODE identifies the system, subsystem and component on which the work was performed. It is decoded using the appropriate Work Unit Code Manual Technical Manual for the equipment identified in Step 2. The specific unit nomenclatured items for which R&M numerics are to be derived would normally be identified at this time utilizing their appropriate Work Unit Codes.

Field MTBF Calculation

1. Correlate the failure data entries with the appropriate equipment operating time logs and eliminate all data entries falling outside of the applicable operating time reporting period. This is accomplished using the JCN Day (columns 69-71), and year (column 34). NOTE: due to delays in entering data into the 66-1 system, the JCN Day must be compared to the 66-1 entry day (column 35-37) to assure validity of the year (column 34) for JCN days late in the calendar year. The days are coded as Julian calendar date numbers and must be translated into their appropriate months to correlate with the equipment operating time logs. All failure data for which applicable equipment operating time logs do not exist must be included.

2. All remaining failure data entries should be grouped by Work Unit Code (utilizing the Work Unit Code Manual) to consolidate all failures against different unit nomenclatured item.

3. Utilizing the applicable maintenance manuals of reliability models, determine the quantity of unit nomenclatures items used per system.

4. Calculate the item MTBF in accordance with the following equation

$$\text{Item MTBF} = \frac{(\text{Number of Items/System}) \times (\text{Number of Systems}) \times (\text{Operating Hours/System})}{\text{Number of Relevant Failures}^*}$$

Field MTTR Calculation

1. Group failure data entries by Work Unit Code (Utilizing the Work Unit Code Manual) to consolidate all failures against each different unit nomenclatured item.

2. Calculate the repair time for each failure by subtracting the Start Time from the Stop Time.

3. Calculate the MTTR by considering all of the applicable failure data entries for each nomenclatured item.

*As defined by the equipment selection and data reduction procedure.

4.2 Identification of Candidate RCM Systems/Equipment

4.2.1 Discussion

A total of 71 systems/equipments were reviewed and identified as candidates for initial inclusion in the RCM during this study. These systems ranged in size and complexity from a single nomenclatured unit such as the AN/ARC-164 to very complex such as the E-3A (Airborne Warning and Control System). TALONS (AN/ARN-101) is an inertial navigational system and is a typical example of the type of system which will be tracked by the RCM. This system is composed of 11 sub-systems which are shown in schematic representation in Figure 4.2-1.

Two basic types of data are required on any of the systems or equipment included in the RCM data base. These two types correspond to the data generated during the development phases which includes specified and demonstrated R&M values, designs and procurement approaches, R&M program provisions, and other similar data associated with the development phases of these systems and equipments. The second basic type of data required for these systems measures the performance of the system under field operating conditions. Currently, estimates of this performance are being made using data obtained from the AFM 66-1 system.

4.2.2 Summary of Results

A summary of the systems/equipment identified during this study for initial inclusion in the RCM is shown in Table 4.2-1. The data type and status of the information associated with each system are listed under two principal headings; contractual plus R&M and field (AFM 66-1). The contractual data refer to all data generated during the systems/equipment development phases and prior to its field operation. The field data are that which are associated with the AFM 66-1 system also discussed in this report. The first twenty of the 71 systems listed in this table have undergone a complete review of those data items available during the

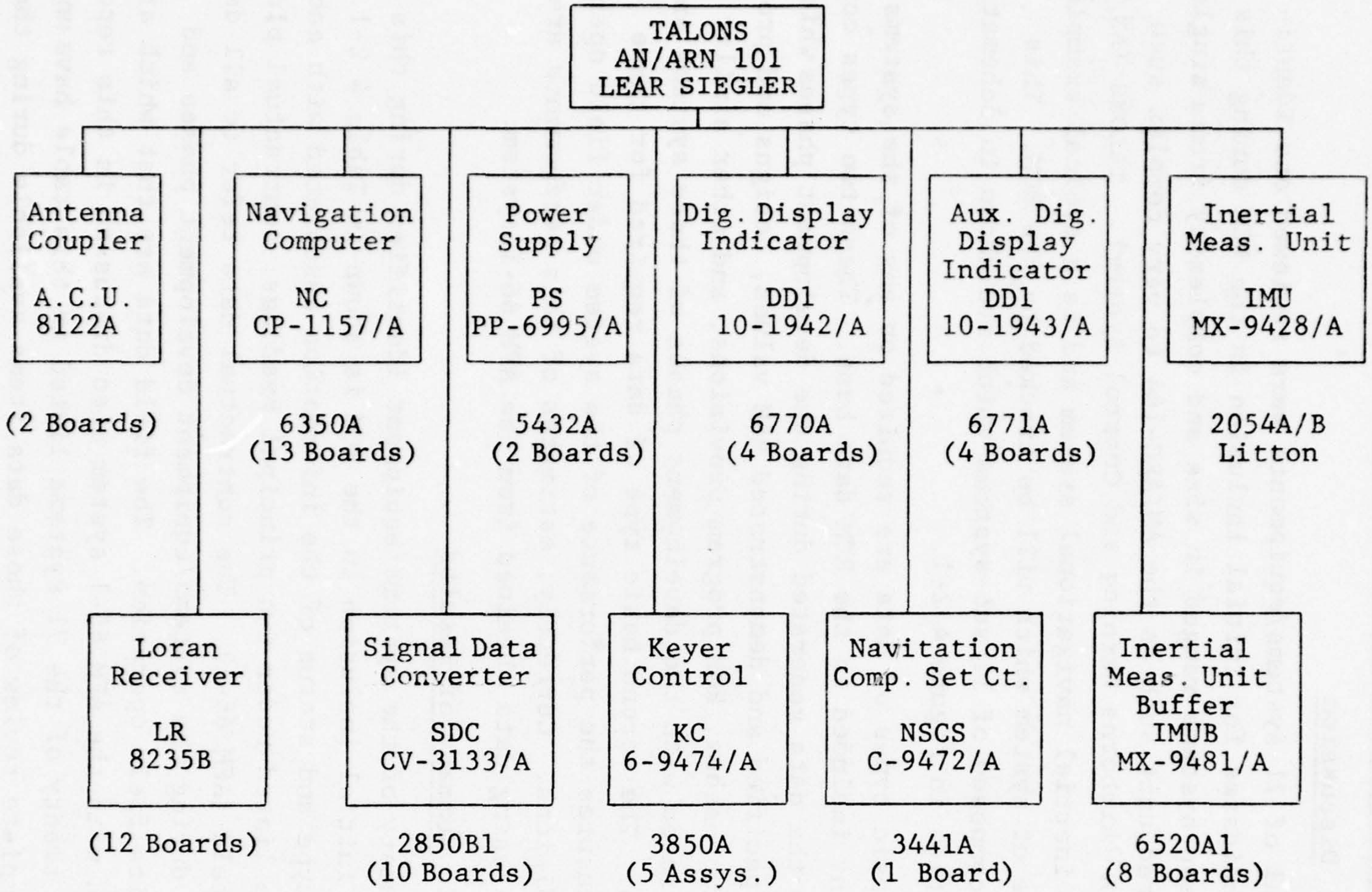


FIGURE 4.2-1 TALONS SUB-SYSTEMS SCHEMATIC

TABLE 4.2-1

	Systems/ Equipment Identification	Data Type and Status					Data in MDQS
		Contractual R&M		Field (AFM 66-1)			
		Review Complete	Under Review	At RAC	Available To RAC	No Field Data	
1	AN/TSC 60 (U)	X		X			X
2	MAU 169/B	X				X	X
3	RASSAR X					X	
4	AN/GSC-24	X			X		X
5	AN/GSC-171	X			X		
6	AN/ARC-162	X				X	
7	TACC	X				X	
8	AN/TPX-42A	X		X			
9	AN/ARN-101	X			X		X
10	AN/ARC-163	X				X	
11	AN/ARC-164	X			X		X
12	AN/ALQ-94	X			X		
13	LORAN D	X			X		
14	SPN/GEANS	X			X		
15	AN/USM-430	X			X		X
16	AWACS	X				X	X
17	FREQ. DIV. MULT.	X				X	X
18	AN/FPS-108	X				X	X
19	TACAN AN/TRN-41	X			X		X
20	AN/USC-26	X			X		X
21	EAR	X			X		
22	AN/TPS-43		X	X			
23	AN/TPS-44		X	X			
24	AN/TPS-48		X	X			
25	AN/PRC-41		X	X			
26	AN/PRC-47		X	X			

SYSTEMS EQUIPMENT SUMMARY

TABLE 4.2-1 (con't)

	Systems/ Equipment Identification	Data Type and Status: Contractual R&M: Review Complete	Contractual R&M: Under Review	Field (AFM 66-1): At RAC	Field (AFM 66-1): Available To RAC	Field (AFM 66-1): No Field Data	Data in MDQS
27	AN/TRC-87		x	x			
28	AN/TGC-26		X	X			
29	AN/TSQ-91(U)		X	X			
30	AN/TSQ-92(U)		X	X			
31	AN/TSQ-93(U)		X	X			
32	AN/TTC-30		X	X			
33	AN/GYQ-18		X	X			
34	AN/GPA-125		X	X			
35	AN/MCC-012		X	X			
36	AN/GYQ-15		X	X			
37	AN/GYQ-17		X	X			
38	AN/GYK-20		X	X			
39	AN/GYC-01		X	X			
40	AN/GIC-21		X	X			
41	AN/GSQ-175		X	X			
42	AN/GSC-28		X	X			
43	AN/GYK-21		X	X			
44	AN/APG-63		X	X			
45	AN/ASK-6		X	X			
46	AN/ASW-38		X	X			
47	CP-1070/AYK		X	X			
48	OP-8638/ARD		X	X			
49	AN/ASN-108		X	X			
50	AN/AUQ-20		X	X			
51	MX-9278A		X	X			
52	AN/MRC-108		X	X			

TABLE 4.2-1 (con't)

	Systems/ Equipment Identification	Data Type and Status: Contractual R&M: Review Complete	Data Type and Status: Contractual R&M: Under Review	Data Type and Status: Field (AFM 66-1): At RAC	Data Type and Status: Field (AFM 66-1): Available To RAC	Data Type and Status: Field (AFM 66-1): No Field Data	Data in MDQS
53	AN/TGC-27		X	X			
54	AN/ALQ-17		X		X		
55	AN/ARC-109		X		X		
56	AN/GRC-106		X		X		
57	AN/ALQ-128		X		X		
58	AN/ALQ-135		X		X		
59	AN/TRN-41		X		X		
60	AN/ALQ-119		X		X		
61	AN/GRC-171		X		X		
62	AN/FPS-108		X		X		
63	AN/ASQ-53		X		X		
64	AN/GPA-124		X		X		
65	AN/FYA-71		X		X		
66	AN/FYH-02		X		X		
67	AN/GEN-00		X		X		
68	AN/GYK-02		X		X		
69	AN/GSM-229		X		X		
70	AN/GSM-230		X		X		
71	AN/ALQ-131		X		X		

development phases and the information thus obtained was transcribed onto data summary forms which are included in Volume II of this report. The data associated with nine of these twenty systems have been further reduced and transcribed into data entry forms for communication with the MDQS Automated Data Processing System. Twelve of the first twenty systems are operational and contributing data to the 66-1 system. These field data are currently available at the Reliability Analysis Center on two of these systems and are available to the RAC for the remaining ten systems. Eight of the twenty systems are in various stages of development or early deployment and there are therefore no field data available on these systems. Thirty-three of the remaining 51 systems identified in this table are operational and are currently being tracked in the field. An additional eighteen systems have been identified by the study as currently generating field data but are not presently part of the RAC 66-1 data library. The necessary steps have been taken to acquire this information and these systems are included in the initial definition of the RCM database.

Descriptions of the nine systems which are in trial use with the MDQS automated data processing system are given in Table 4.2-2. A brief description of each of the 71 systems is included as Appendix D of this report.

TABLE 4.2-2

SYSTEM DESCRIPTIONS

1) The AN/TSC-60 is a ground, transportable, HF communication facility. It has various single sideband communication modes including voice, tone modulated CW, multichannel VFTG, TTY, and compatible AM. The system is capable of different power outputs up to 10 KW dependent upon configuration and is capable of both local and remote operation. The TSC-60 is a complex system containing 9 or more subsystems and approximately 50 individual nomenclatured units. The TSC-60 was manufactured by Collins and is currently deployed.

2) The NAV-169/B Paveway II system is a Laser Guided Bomb. Limited data are presently available on the Computer Control Group (CCG) portion of this system manufactured by Texas Instruments. The purpose of the CCG is to functionally control the laser guided bomb by passively homing on a laser illuminated target and providing aerodynamic directional control to the bomb. The CCG is composed of three units and is currently in production.

3) The AN/GSC-24 is a ground based multiplexer set manufactured by Martin Marietta and used in the Defense Communications System (DCS). It is used to combine a number of digital channels into a single, time-division multiplexed, digital data signal. The GSC-24 provides full duplex asynchronous time division multiplexing and simultaneous demultiplexing functions. It is a single nomenclature unit and is at present operationally deployed.

4) The AN/ARN-101 (TALONS) is an integrated LORAN - Inertial Navigational System developed and manufactured by Lear Siegler Loran time difference measurements are processed simultaneously with inertial location measurement and combined to present positional location data more accurate than that based on either input alone. The system also offers five alternate degraded modes of operation. The system is composed of ten nomenclatured units. The system is presently in production.

TABLE 4.2-2 (CONT'D)

SYSTEMS DESCRIPTION

5) The AN/USC-26 Group Data Modem provide the necessary signal processing to permit the transmission of synchronous, serial data over standard military group bandwidth circuits at rates between 19.2 and 153.6 kilobits per second over channels with a variety of impairments such as noise, jitter, etc. The USC-26 manufactured by Honeywell is a single unit containing 30 subassemblies and is at present operationally deployed.

6) The AN/ARC-164 is a 7000 channel airborne UHF transceiver developed and manufactured by Magnavox. It has a 10 watt transmitter output and utilizes both a main and a guard receiver. The ARC-164 is a single nomenclatured unit and is presently in production.

7) The E-3A Airborne Warning and Control System (AWACS) is an Airborne S-Band Surveillance Radar System. It utilizes a 360° mechanically rotating antenna with phased array electronic elevation scanning. It is a very large complex system consisting of eight major subsystems. most of which are subcontracted to different subcontractors, and numerous individual boxes. Boeing is the prime contractor and the system is presently in production.

8) AN/USM-430 is an electronics systems test set for UHF communications equipment.

9) Frequency Divider Multiplexer Set. The set is designed to operate in conjunction with other elements of the internal communications subsystem on board the Airborne Command Post aircraft. This sytem provides full duplex communications capability. It interfaces the UHF radio element to the internal voice communications system via the switchboard.

4.3 RCM Data Input Procedures

4.3.1 Data Reduction and Transcription

Data acquisition procedures ultimately result in the receipt of information, generally in the form of documents, which must be processed and prepared for use in the RCM Automated Data Storage and Retrieval System. This requires two steps using data forms designed to receive this information.

Two sets of corresponding forms were designed for this purpose during this study. The first set are the Data Summary Forms which are completed by a qualified Reliability Engineer who has the responsibility of interpreting and converting certain information contained in the raw data into a concise pattern prescribed by the Data Summary Forms. The second step in this process consists of transcribing the information contained in the Data Summary Forms onto Computer Data Entry Forms. These are used by the data specialist who enters the data into the Automated Data Management System. The design of the Computer Data Entry Forms is based on the Data Management system and specifies each coded entry to correspond to machine recognizable language. As experience is gained in reducing and summarizing data the intermediate step is expected to be eliminated.

4.3.2 Design of the Data Summary Form Set

The design of the Data Summary Form was based upon a set of core descriptors which define the most essential aspects of the data input requirements. This list of descriptors is shown in the Input Data Requirements Matrix (Figure 4.3-1) along with the applicable Life Cycle Phase. The information categories conveyed by these descriptors can be logically organized into four data files. It was determined that a minimum of six Data Summary Forms were sufficient to complete these files for any one system. (Ongoing data collection during an operating phase might require that a form be completed more than one time.)

Figure 4.3-1. INPUT DATA REQUIREMENTS MATRIX

INPUT DATA Descriptors	LIFE CYCLE PHASE				
	CONCEPT	VALIDATION	DEVELOPMENT	PRODUCTION	OPERATIONAL
1. System Description	•	•			
2. Performance Characteristics	•	•			
3. Physical Characteristics		•	•		
4. Procurement Type	•				
5. Reliability Level & Provisions	•	•			
6. Diagnostic Level		•			
7. Replacement Level		•			
8. Criticality Level	•				•
9. Complexity Level	•	•			
10. Reliability Design Features			•		
11. Production Reliability Characteristics			•	•	•
12. O&M Reliability Characteristics			•	•	•
13. Maintainability Design Features			•		
14. Support Factors		•	•		
15. Compliance Techniques		•	•		
16. Acquisition Cost & Factors	•	•	•	•	
17. Support Cost	•	•	•	•	•

These Data Summary Forms were used to abstract data from CDRL items on twenty systems and equipment, and were also used in interviews to collect data on five of these systems. The completed Data Summary Forms are included in Volume II of this report as examples of the raw data input to the Reliability Corporate Memory. Since the design of the Data Summary Forms attempted to provide a comprehensive instrument for recording program data, not all data items will be uniformly available from every systems development program, leaving unavoidable but anticipated absence of certain data items. A shorter version of these forms was also devised to clarify the programming tasks associated with the entry of data into the automated data management system.

4.3.3 <u>Procedures for Systems/Equipment Data Transcription</u>

The completion of these Data Summary Forms is occasionally an interpretive procedure placing the transcriber in judgment areas. In order to assure some uniformity of these judgements, procedures were developed to systematize the data transcription activities.

The procedures outlined in this section were developed to explain and standardize the transcription of systems/equipment data onto the Data Summary Forms previously discussed. The procedures are presented in the following order:

1. Procedures for Program Data Summary Form
2. Procedure for Technical Data Summary Form
3. Procedure for Financial and Support Data Summary Form
4. Procedure for Reliability Data Summary Form
5. Procedure for Maintainability Data Summary Form
6. Procedure for Program Effectiveness Form

With exception of Item 6, each procedure is followed by an example of that portion of the form set which has been completed for one of the systems reviewed in this study. The text of each procedure and the corresponding examples are presented in Appendix C.

The RCM data would be composed of four separate files containing a total of approximately 180 fields. Each of the four files would also contain one subsumed file for additional narrative data. The four data files are:

- I Program Data
- II Technical Data
- III Financial/Support/Effective Data
- IV R&M Data

The RCM data input would consist of a series of six data input forms. These six forms are:

1) Program Data Summary
2) Technical Data Summary
3) Maintainability Data Summary
4) Financial and Support Data Summary
5) Reliability Data Summary
6) R&M Program Effectiveness Summary

Five of the six forms contain objective program data gleaned from various program data sources such as the contract, procurement specification, CDRL data items, applicable field performance reporting systems and other applicable supporting documentation. The sixth form, "R&M Program Effectiveness Summary", is more subjective in nature. It is used by the RCM professional staff and other qualified personnel, such as R&M program managers, to evaluate the R&M aspects of the program.

Examples of the Data Summary Forms are shown in Figures 4.3-2 through 4.3-9. A general description of the use of each form is discussed and the specific data content is described by the form itself.

1) Program Data Summary (Figures 4.3-2, 4.3-3)

   This form contains all of the Program oriented data. A separate Program Data Summary Form is completed for each contract, since different contracts contain different

PROGRAM DATA SUMMARY FORM

SYSTEM DESCRIPTION: Nomenclature ______________________

Identification No. ______________________

Contractor ______________________ Contract No. ______________________

Mission Function ______________________

Data Date: Initial ____________ Current ____________ Design Vintage Yr. ____________

Source Document Acces. Nos. ____________ ____________ ____________ ____________

PROCUREMENT LEVEL

- System ☐
- Subsystem ☐
- Functional Group ☐
- Component/Box ☐

USE ENVIRONMENT

- Space ☐
- A/C ☐
- Ground ☐
- Other ☐

LIFE CYCLE PHASES

	Contract Applicable	Date
Concept	☐	____
Validation	☐	____
Development	☐	____
Production	☐	____
Deployment	☐	____

MISSION LENGTH

Continuous or not Defined ☐ >8 hrs. ☐ 1 hr. to 8 hrs. ☐ <1 hr. ☐

HISTORICAL SUMMARY ☐ (Subsume)

____

____

____

CONTRACT DESCRIPTION

PROCUREMENT TYPE

- Existing System ☐
- Modified Existing ☐
- New Design ☐
- Combination of above ☐

R FINANCIAL POSTURE

- R Incentive Awards ☐
- R >5% of Budget ☐
- R < 5% of Budget ☐
- Not Determined ☐

TYPE OF CONTRACT

- Design to Cost ☐
- R I W ☐
- Reliability Incentive ☐
- Fixed Price ☐

PROCUREMENT APPROACH

Low Bidder ☐ Minimum LCC ☐ Minimum Support ☐

FIGURE 4.3-2

PROGRAM DATA SUMMARY FORM (Page 2)

R&M PROGRAM PROVISIONS

APPLICABLE DOCUMENTS	CONTRACTURAL	LIMITED	GUIDE	N/A
MIL-STD-470	☐	☐	☐	☐
MIL-STD-471	☐	☐	☐	☐
MIL-HDBK-472	☐	☐	☐	☐
MIL-STD-756	☐	☐	☐	☐
MIL-STD-781	☐	☐	☐	☐
MIL-STD-785	☐	☐	☐	☐
MIL-HDBK-217	☐	☐	☐	☐
RADC Notebook	☐	☐	☐	☐
MIL-HDBK-217B	☐	☐	☐	☐

R&M ANALYSIS

- R&M Analysis and Pred. per MIL-STD-757 & 472 ☐
- R or M Analysis and Pred. ☐
- Informal Analysis and Pred. ☐
- No Req't ☐

R&M NUMERICS

- Contractural MTBF & MTTR ☐
- Contractural MTBF or MTTR ☐
- MTBF/MTTR Design Goals ☐
- No Req't ☐

DESIGN SURVEILLANCE

- $\geq$ 2 Formal Design Reviews ☐
- 1 Formal Design Review ☐
- Informal Review Only ☐
- Rel. Growth Management ☐
- None Required ☐

FAILURE REPORTING AND CORRECTIVE ACTION

- Formal Failure Reporting and Closed Loop Corrective Action System Required ☐
- Formal Failure Reporting Only ☐
- Informal Failure Reporting Only ☐
- Not Required ☐

DEMONSTRATION REQUIREMENTS

- Formal R&M Demo required per MIL-STD-781 and 471 ☐
- Formal R or M Memo Required ☐
- Other Demo Req'ts ☐
- None Required ☐

DEVELOPMENT TESTS

- Design Qualification ☐
- Environmental Qualification ☐
- R Growth Test ☐
- Competitive Fly-off ☐

PRODUCTION INSPECTION

- Sampling Inspection ☐
- 100% Acceptance Test ☐
- Processing Screening ☐
- Reliability Verification per MIL-STD-781 ☐

R&M EFFECTIVENESS

- High ☐
- Medium ☐
- Low ☐

FIGURE 4.3-3

R&M provisions. This is especially true when different contracts are used for development and for production of the same system/equipment. The Program Data File would contain approximately 35 fields. It would also contain one subsumed file to be used for historical narrative information.

2) Technical Data Summary (Figures 4.3-4 and 4.3-5)

This form contains all of the technical data for a single System, Sub-System, or lower nomenclatured item. Separate summaries are completed for each nomenclatured item and for each identifiable higher level group. subsystem or system covered by the applicable contract. The Technical Data File would contain approximately 70 fields. It would also contain one subsumed file to be used for any necessary narrative remarks or comments. A unique aspect of the technical data form is the fact that the parameter definition for approximately 29 of these fields is a variable dependent upon the type of equipment covered. The definition of these fields is defined by the choice of equipment type in another specific field.

3) Maintainability Data Summary (Figure 4.3-6)

A separate Maintainability Data Summary would be completed for each data entry against each nomenclatured item, group, sub-system, and system covered by each separate contract. This maintainability data would be gleaned from specifications, AAA reports, periodic maintainability reports, demonstration test reports and field reporting systems.

4) Financial and Support Data Summary (Figure 4.3-7)

This is a single sided form containing all of the financial and support data for a single contract.

TECHNICAL DATA SUMMARY FORM

EQUIPMENT DESCRIPTION: Nomenclature ____________________
Identification No. ____________________

Manufacturer ____________________ **Contract No.** ____________________

Data Date: Initial __________ Current __________

Source Document Acces. Nos. __________ __________ __________ __________

DATA LEVEL Used on/Higher Assy.

Subsystem ☐ Nomenclature ____________________

Equipment ☐ Identification No. ____________________

PERFORMANCE CHARACTERISTICS **CRITICALITY**

High ☐ Medium ☐ Low ☐

CATEGORY

Radar ☐	Computer ☐	Controls/Displays ☐	Weapons ☐
Communications ☐	ECM/EW ☐	Guidance/Navigation ☐	Other ☐

DESIGN APPROACH

1 ☐ ______	3 ☐ ______	5 ☐ ______	7 ☐ ______
2 ☐ ______	4 ☐ ______	6 ☐ ______	8 ☐ ______

TECHNOLOGY

1 ☐ ______	3 ☐ ______	5 ☐ ______	7 ☐ ______
2 ☐ ______	4 ☐ ______	6 ☐ ______	8 ☐ ______

MAJOR PARAMETERS

1	______	11			______
2	______	12			______
3	______	13			______
4	______	14	Weight	(lbs)	______
5	______	15	Volume	(cu. ft.)	______
6	______	16	No. of Modules		______
7	______	17	Height	(in.)	______
8	______	18	Width	(in.)	______
9	______	19	Depth	(in.)	______
10	______	20	Power Consumption	(watts)	______

REMARKS ☐(Subsume)

____

____

____

FIGURE 4.3-4

TECHNICAL DATA SUMMARY FORM (Page 2)

RELIABILITY DESIGN FEATURES:

FAULT TOLERANCE		PART DERATING GUIDELINES		PART QUALITY GRADE/ SCREEN CLASS	
Redundant Channel/Equip.	☐	High Rel.	☐	TXV, JAN 38510	☐
Graceful Degradation	☐	Intermediate	☐	TX MIL-STD-883	☐
Degraded Modes	☐	Normal Commercial	☐	Jan , Hermetic	☐
None	☐			Commercial, Plastic	☐

MAINTAINABILITY DESIGN FEATURES:

EXTENT OF BUILT-IN TEST		BIT METHODOLOGY		BIT IMPLEMENTATION	
Performance Monitoring	☐	Software Controlled	☐	G. P. Computer	☐
Fault Detection	☐	Hardware Controlled	☐	Microprocessor	☐
Fault Isolation	☐	Manual	☐	Hardwired Controller	☐
None	☐	Combination	☐	Panel Meters	☐

DIAGNOSTIC LEVEL		REPLACEMENT LEVEL		TYPE OF COOLING	
Equipment	☐	Equipment	☐	Ambient Air	☐
Unit	☐	Unit	☐	Forced Air	☐
Assy	☐	Assy	☐	Liquid	☐
Part	☐	Part	☐	Other	☐

COMPLEXITY/ACTIVE ELEMENTS:

NUMBER OF PARTS	NUMER OF PART TYPES	NUMBER OF ACTIVE ELEMENTS
________	________	________

ACTIVE ELEMENT TYPE	ACTIVE ELEMENT COUNT
Tubes	________
Discrete Semiconductors	________
Hybrid ICs	________
Monolithic Linear ICs	________
SSI/MSI Digital ICs	________
LSI ICs	________
Microprocessors	________

FIGURE 4.3-5

MAINTAINABILITY DATA SUMMARY FORM

	NOMENCLATURE	IDENTIFICATION NO.
System Identification	________	________
Subsystem Identification	________	________
Equipment Identification	________	________

Data Date ____________ Contract No. ____________________

Source Document Accession No. ________________________

MAINTAINABILITY PARAMETER

	Organization	Intermediate
MTTR (M_{CT})	☐	☐
M_{Max} (95%)	☐	☐
M_{Max} (90%)	☐	☐
M_{PT}	☐	
MMH/FH/Operating Hr	☐	
Mean Down Time	☐	
BIT Effectiveness	☐	

DATA TYPE

- Specified/apportioned ☐
- Predicted ☐
- Demonstrated ☐
- Flight/Field Test ☐
- Operational ☐

PROGRAM PHASE

- Development ☐
- Production ☐
- Operational ☐

M Numeric ____________

BIT EFFECTIVENESS

	ON LINE/AUTOMATIC	OFF LINE/INITIATED
FAULT DETECTION		
Capability	_____ %	_____ %
False Alarms	_____ %	_____ %
FAULT ISOLATION		
to (1) LRU/SRU	_____ %	_____ %
to _____ or less LRU/SRUs	_____ %	_____ %

FIGURE 4.3-6

A separate financial and support summary is required for each contract. The financial and support data are obtained from the applicable proposal, the contract, financial CDRL data items and using commands. These data, together with the R&M Program Effectiveness Summary, form a single file with approximately 55 fields. The file would also include a subsumed file containing narrative regarding application acquisition factors.

5) Reliability Data Summary (Figure 4.3-8)

This is a simple single sided form and would be the most frequently completed form. A separate Reliability Data Summary would be completed for each data entry against each nomenclatured item, group, sub-system and system covered by each separate contract. These reliability data would be gleaned from specifications, AAA reports, periodic reliability reports, demonstration test reports and field reporting systems. The reliability data summary would comprise a single Reliability and Maintainability Data file containing approximately 20 fields. It would also contain a subsumed file for applicable narrative.

6) R&M Program Effectiveness Summary (Figure 4.3-9)

This is a single sided form found on the reverse side of the financial and support data summary. A separate R&M Program Effectiveness Summary is required for each contract. This form is subjective in nature and contains the evaluator's appraisal of the R&M aspects of the program. Multiple R&M Program Effectiveness Summaries may be completed on a single contract if additional independent appraisers are available. This is only a working form with the effectiveness value entered into the RCM data base in the Technical Data File.

FINANCIAL AND SUPPORT DATA SUMMARY FORM

Nomenclature

Identification No. __________ Contract No. __________

Source Document Acces. No. __________ __________ __________ __________

ACQUISITION COST

	ESTIMATED/PROPOSED	ACTUALS
R&D cost		
Test & Evaluation Cost		
Non-Recurring Production Cost		
Recurring Production Cost		
Quantity Procurred		

ACQUISITION FACTORS (Subsume)

SUPPORT COST

	LCC MODEL INPUTS	ACTUALS
Initial and Pipeline Spares		
Replacement Spares		
On-Equipment Maintenance		
Off-Equipment Maintenance		
Inventory Entry and Supply Management		
Support Equipment		
Personnel Training and Training Equipment		
Technical Data and Documentation		
Logistics Management		

SUPPORT FACTORS

APPLICABLE MAINTENANCE & ECHELONS	SKILL LEVEL	NO. OF PERSONNEL	LOWEST LRU/SRU SPARING
Organization (Field) ☐			☐
Intermediate (Shop) ☐			☐
Depot/Plant ☐			☐

LRU/SRU REPAIR STRATEGY		SITE MAINTENANCE LEVEL	
Throw Away	☐	LRU	☐
Intermediate Repair	☐	SRU	☐
Depot Repair	☐	Part	☐

FIGURE 4.3-7

RELIABILITY DATA SUMMARY FORM

	NOMENCLATURE	IDENTIFICATION NO.
System Identification	______	______
Subsystem Identification	______	______
Equipment Identification	______	______
Data Date ______ Contract No.	______	______
Source Document Accession No.	______	
R Numeric ______ hours		

PROGRAM PHASE

- Development ☐
- Production ☐
- Operational ☐

RELIABILITY PARAMETER

- Series (Logistics) MTBF ☐
- Functional MTBF ☐
- MTBM ☐

DATA SOURCE

- Contract/Specification Req't ☐
- Allocation ☐
- Analysis and Prediction Report ☐
- Demonstration Test Report ☐
- Production Sampling Verification Test Report ☐
- SEDS Data and Operating Time ☐
- 66-1 Data and Flight Time ☐
- 66-1 Data and Actual Operating Time ☐
- Other (explain) ☐

DATA LEVEL

- System ☐
- Subsystem ☐
- Equipment ☐
- Failures ______
- Operating hours ______
- Non-Operating hours ______
- Failures Relevant ______
- Failures Non-Relevant ______

REMARKS ☐ (subsume)

______
______
______
______
______
______

FIGURE 4.3-8

R&M PROGRAM EFFECTIVENESS FORM

		WEIGHT	SOURCE
1.	Were all of the original R/M program requirements completed in their entirety?		
2.	Were some R/M items subsequently eliminated or reduced due to dollar or schedule constraints? If so, which ones, and why?		
3.	As the program progressed did the attention to the R/M requirements increase, decrease, or stay the same?		
4.	Did significant management changes or organizational changes occur during the program affecting either the contractor or the procuring agency?		
5.	If so, did this change the attitude of either or both regarding the R/M requirements?		
6.	Were there major program changes in the course of the program such as a significant reduction in the number of items to be procured, program stretch-outs, mission definition changes, etc.?		
7.	How did these program changes affect the R/M requirements?		
8.	Did major ECPs/design changes occur as a result of R/M deficiencies uncovered during: a. manufacturing b. contractor's tests c. demonstration tests d. field deployment		
9.	Were there major problem areas uncovered during the PDR/CDR?		
10.	If so, were these resolved in a timely manner to the satisfaction of both the contractor and the procuring agency?		
11.	Did significant cost overruns occur on the program? To what were these attributed?		
12.	Were R/M deficiencies significant contributors to any cost overruns?		
		100	

High R&M Program Effectivity	>90
Medium R&M Program Effectivity	50 - 90
Low R&M Program Effectivity	<50

FIGURE 4.3-9

4.4 Automated Systems/Equipment Data Management Procedures

Data Base Management Systems

The Information Sciences (IS) Division of RADC is currently maintaining two Honeywell 6180 computer systems to provide services for various computation needs at RADC. Both the GCOS and Multics Operating System are available.

Seven data base management systems utilizing GCOS and Multics, have been examined for possible use during the course of other RAC investigations. During these investigations a system of choice was identified and has been used to process data on a selected number of systems which have been identified in this study. The characteristics of each candidate data base management system are summarized in Table 4.4-1, including the designation of the appropriate operating system, the organization responsible for maintaining the system at RADC, and an indication of whether its strengths are in the area of self contained capabilities or host language capabilities. The data base management system which was selected as a result of these considerations and used in these studies was the Management Data Query System (MDQS).

In preparation for the use of this system, a series of data entry forms were designed to facilitate the entry of systems/ equipment data into the data base.

TABLE 4.4-1

DATABASE MANAGEMENT SYSTEM CHARACTERISTICS

Database Management System	Operating System	Maintenance	On-Site Maintenance	DEM Type
Data Manager - 1 (DM-1)	GCOS	--	--	Host Language
JANUS	Multics	MIT	--	Self-contained
Integrated Data Store (I-D-S)	GCOS	HIS	HIS	Host Language
Management Data Query System (MDQS)	GCOS	HIS	HIS	Self-contained
Force Management Information System (FMIS)	GCOS	SAC	--	Self-contained
Multics Relational Data Store (MRDS)*	Multics	HIS	--	Host Language
Multics Integrated Data Store (MIDS)*	Multics	HIS	--	Host Language

* These Systems are new Multics releases and their capability has not yet been established.

4.5 Document Library Implementation

4.5.1 Operation

The operation of a document library is a key element in the functioning of the RCM. The library will provide capabilities in several areas, the primary one of which will be the accession, indexing and storing of documentation associated with those systems/equipment items of interest to the RCM and its users. In addition, however, the document library must function as a repository of the information generated by the RCM and, most importantly, the library should aggressively pursue and accumulate state-of-the-art articles and information which can be digested and disseminated to the user clientele. Thus, the document library must be envisioned as an aggressive part of the RCM with the mandate for becoming a singular comprehensive source of R&M materials and information.

4.5.2 Document Indexing

The primary need of the document library is one common to all libraries - the need for an efficient storage and retrieval system.

In order to provide optimal satisfaction of user's needs, the library requires:

1. A means of selecting documents containing information relevant to the purpose of its users.
2. A means of describing (indexing) such documents in an accurate consistent manner so that they can be subsequently retrieved upon the user's request.
3. Convenient storage and accessibility to both the documents and the indices describing these documents.
4. The ability to manipulate indexed information for search and retrieval.
5. Some form of meaningful, organized output to describe the results of a search.

As noted above, the RCM will contain two broad classes of documentation; a) documents associated with those systems and equipments of interest to the RCM and its users. These documents are intended to serve as detailed backup and supporting information to the computerized RCM data base; b) state-of-the-art study reports, technical articles and other published papers related to R&M or cost.

A reasonable assumption that can be made, considering the potential size of RCM activity, is that bibliographic citations and abstracts of the documents contained in the library will be stored in a computerized data base (THE DOCUMENT DESCRIPTION DATA BASE). There are, however, alternative methods for handling information whose effectiveness depends upon both the size and utilization of the library. Because of the differences in how the two basic information types will be used, separate approaches may prove to be most efficient.

Technical reports would be thoroughly indexed with full bibliographic citation plus assigned key words. Key words are assigned as part of the input processing function by experienced reliability engineers. This indexing process requires careful review of the document's contents and attempts to identify the important concepts that may be of interest in the future. Depending upon the nature of the document, and the breadth of important topics covered a given document may be indexed with from 10 to 30 or more key words. It is thus seen that a computerized document retrieval system can be invaluable for searching out reference sources on a specialized subject.

An open-ended subject term (keyword) thesaurus would be developed and maintained to aid the indexing task and minimize the proliferation of related but variations in terms. Continued attention to thesaurus control is necessary to restrict the use of obsolete terms and add new ones to reflect changing patterns of usage and technology.

A simpler cataloguing and indexing system is sufficient for those documents associated with particular systems or equipments. Generally, access to these documents would be either by system designation or cross-references from the computer data base. Also, the total number of systems catalogued at any one time is expected to be relatively small. Consequently, a computer retrieval system does not appear warranted. Instead, manual cataloguing methods are appropriate. Typically, 5x8 index cards in conjunction with several cross-referenced index files. The major designator of interest is system designation. Within each major system, one is interested in nomenclatured subsystems and equipment items. A further segregation by document type and identification should provide the essential cross-reference to the hard copy documents stored in the library.

4.5.3 Document Storage

The majority of documents acquired by the RCM will be hardcopy. These are best stored in individual folders in file cabinets. The assigned accession number will serve as the primary means of organization for general technical reports and related publications. The folder for each document also contains its indexing form showing all of the terms (including bibliographic citations) by which it has indexed as means for retrieval verification.

Individual document accession numbers will not be assigned to system related documents. Instead, all documents pertaining to a given system (or nomenclature equipment in the absence of a complete system) will be grouped together for convenience of retrieval. Although the detailed methodology has not been definitized, a single accession is expected to serve for each system. Individual documents may be assigned subaccessions to aid in locating them within the system file.

A document sign-out procedure will be implemented to control the lending of catalogued documents. It is expected that documents will be withdrawn for review and study only by RCM and RADC personnel, or by outsiders at the RCM facility. No documents will be sent out on loan nor will the RCM serve as a document distribution center, duplicating its source documents for external distribution.

4.6 RCM Outputs and Technical Services

4.6.1 Discussion

The RCM is intended to serve organizations and individuals responsible for acquisition, development, production and deployment of military electronic system/equipment hardware. This includes both government and contractor activities and encompasses management personnel as well as technical specialists. More directly, RCM users can be broadly classified in two groups:

1) reliability researchers,
2) reliability engineering practitioners.

The first group is concerned with the development and validation of theoretical concepts, analytical models and viable tools and techniques that can be applied to force reliability control improvement and growth during the development/production phases. Reliability practitioners are responsible for utilizing the available tools, techniques and historical data plus their own ingenuity during design, production and testing and deployment to assure that operational objectives are satisfied.

The information and data needs of this body of users were determined by:

1) letter survey of reliability specialists in government and industry,
2) personal interviews with government and contractor representatives,
3) review of current system reliability technical literature,
4) informed discussions with reliability engineering personnel.

It is evident from these meetings and reviews that the RCM outputs and services must be quite varied and diverse. For example, one result of the letter survey of prospective users (see Appendix A) identified twenty three (23) unique types of output

data that were of interest to over 50% of the respondees. Those types having highest interest level include:

1) operational MTBF experience,
2) benefits derived from part level screening (MTBF),
3) MTTR ratios-predictions/observed,
4) demonstrated vs. predicted MTBF,
5) operational MTBF vs. part quality grade,
6) modeling of operational/maintenance degradation,
7) MTBF ratios-predicted vs. demonstrated vs. observed.

This suggests that, while a small number of standard outputs might be appropriate, the RCM must be prepared to respond to user information requests that would require special studies and data analysis. These can be treated as four general classes of outputs as follows:

1) Direct tabular printouts of systems/equipment data organized into report form.
2) Systems/equipment tracking; graphic presentations of performance indices as functions of time and other merit descriptors.
3) R&M models developed and applications: available models covering such areas as prediction by function, optimum repair level analysis, reliability allocation and apportionment, life cycle costing, etc. would be maintained, and updated and new models developed, refined and validated.
4) Special studies: RCM and/or user generated problems which require solutions based on some unique organization or analytical interpretations of the available data.

These basic output types would draw upon the automated data system capabilities as described in Section 3.0, but specific outputs would be prepared under the control and direction of reliability engineering specialists.

Within each basic output type there exists a sizable number of specific investigations and/or reports that may be produced.

No distinction is being made at this time between regularly scheduled and on demand outputs. There can be some of each within any of the form general output types. That is, a specifically formatted tabular printout could be produced periodically as a 'standard' output. Likewise, a tabular listing may be produced as a result of a user inquiry resulting in a formatted listing of selected field from data records meeting the search specification.

It is anticipated that the RCM will produce a set of standard outputs selected on the basis of interest level.

Implementation of specific outputs will be evolutionary. In addition to the potential user interest, the decision will be predicated on the ability of the data resources to support the particular report and the computer software system capability. As data resources, analysis capability and expressed user demands expand, additional outputs will be designed and produced.

4.6.2 Direct Printout Report

This output class lends itself to the production of a wide variety of reports. The existing software capability enables relatively simple specification of report content, format and sorting order. Because of the ease in generating this type of output, it is anticipated that most early RCM outputs will be of this form. If needed, subsequent analyses can be performed manually by staff engineers.

Table 4.6-1 illustrates the format of typical tabular reports. Those shown, MTBF BY EQUIPMENT CLASS and GROSS LEVEL MTBF, would be supportable by the early RCM data base and might serve as prototypes for initial standard outputs. Many other variations of this basic report are possible either as standard outputs or on demand. Most responses to direct inquires for selected data items meeting a specified search criterion would be formatted in this manner.

TABLE 4.6-1 TYPICAL TABULAR DATA OUTPUTS

(a) MTBF BY EQUIPMENT CLASS

RELIABILITY CORPORATE MEMORY   DATE ISSUED: ____________

EQUIP CTGY	NOMENCLATURE	DES YR	USE ENV.	RIM REQ	PART QUAL	DATA SOURCE	DATA DATE	MTBF (HRS)	FLRS	OPER HOURS

(b) GROSS LEVEL MTBF

USE ENV	DATA SOURCE	DESIGN YEAR	DERAT PRCTC	DEV TESTING	MTBF HRS	FLRS	OPER HOURS

4.6.3 System/Equipment Tracking

A primary capability of the operational RCM will be R&M tracking of selected systems and equipments. To aid interpretation, this class of outputs is graphical with each plot providing history on a particular system or equipment. Two variations are illustrated in Figure 4.6-1. Figure 4.6-1(a) portrays the applicable MTBF value at each life cycle phase for which data are on file. A variation would plot values as a percentage of some reference MTBF such as the specified or predicted value.

Figure 4.6-1(b) is applicable for system/equipment that have been fielded for some period of time. It plots observed MTBF by calendar period (quarterly as shown --other time periods could be selected). In addition, a 12 month (or other selected time period) moving average is plotted along with the predicted values. Both output variations would be accompanied by a system equipment identification sheet.

Distribution of this class of outputs would be limited to special requests, although qualified users may arrange for its preparation on a continuing automatic basis.

4.6.4 Model Development and Application

One of the more important output functions of the RCM is the development and validation of R/M and cost models and algorithms. One conceptual goal of the RCM is to establish the effects of design, process, and application variables on reliability, maintainability and cost. Achievement of this goal would permit extension of reliability theory into a more scientific realm. As this is being accomplished, the RCM would serve as a repository of available models and utilize its data resources for testing, validating, refining and extending these models. Some of these are: reliability prediction by function; optimum repair level analysis; prediction by parts count; reliability growth models; life cycle costing models, etc. In addition,

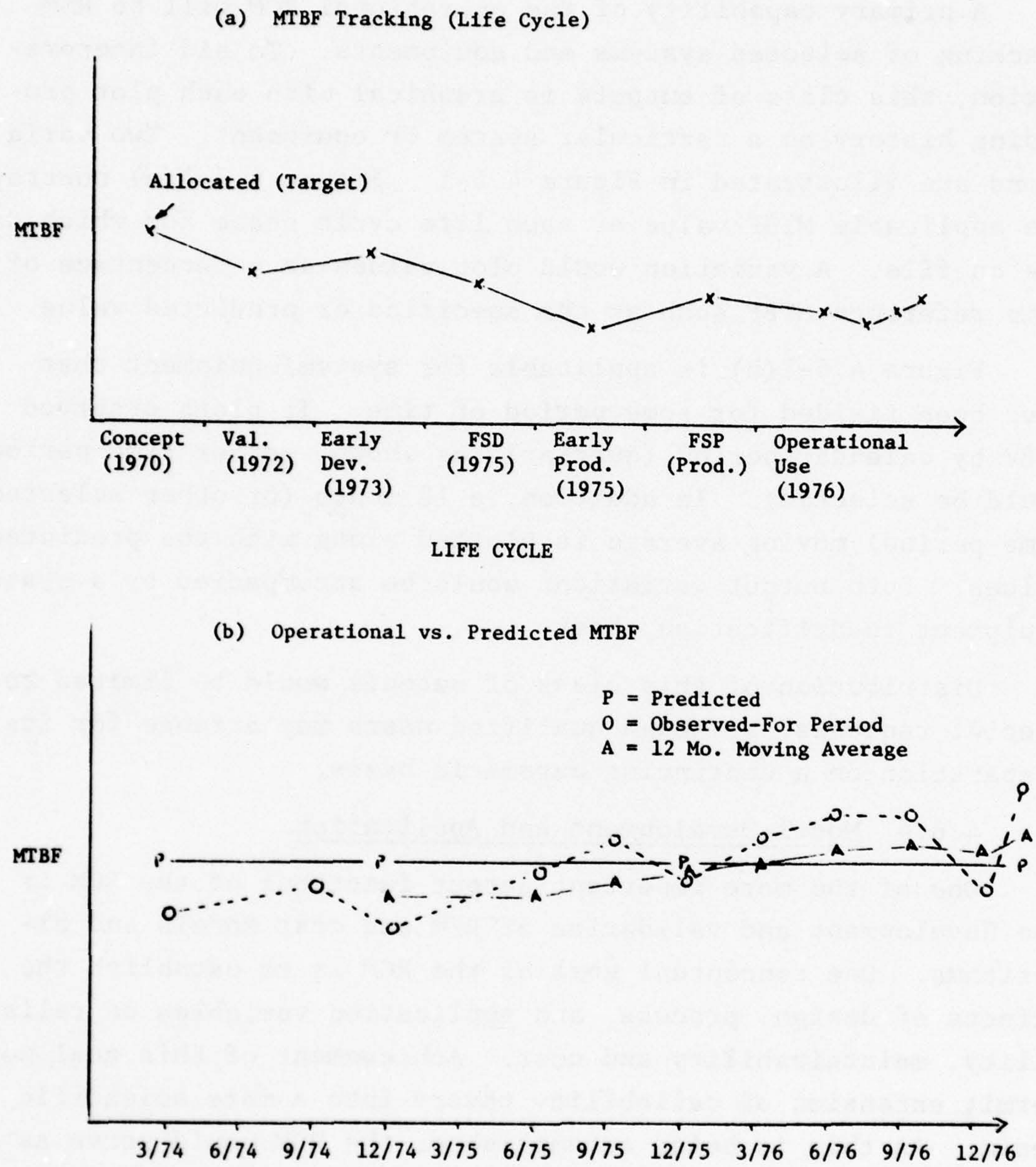


FIGURE 4.6.1 EXAMPLE R/M TRACKING OUTPUTS

other more advanced models which would include more detailed design, assembly and reliability control factors would be hypothesized and evaluated. Computer analysis and simulation techniques such as multi-regression analysis, sensitivity analysis, parametric curve fitting and other advanced analysis methods would be employed in carrying out these functions.

The operating RCM would be prepared to employ its accumulated data resources for conducting special studies. These studies may be internally initiated to evaluate, for example, some particular aspect of the applied R/M control program, to determine why the reliability of a particular system is not tracking as expected, or to develop handbooks or guidebooks for broad distribution. Studies may also be in direct response to a user's problem or request for guidance and support.

Special studies are essentially intellectual efforts by RCM staff engineers. They may call upon any or all of the computerized data processing and analysis capabilities in pursuing this work. Certain parts, and in some situations the majority of the effort, may require evaluation of textual documentation and related information from the RCM document library, and an occasional special survey.

Of broad interest to users would be graphical outputs portraying a dependent variable (i.e., MTBF, MTTR or Cost) against a selected independent variable. With the data descriptors incorporated into the RCM data file structure a large number of unique plots can be generated depending upon the user's interest. Table 4.6-2 itemizes some of the data descriptors (independent variables) which may be of interest. The three dependent variables (MTBF, MTTR, and Cost) are shown in the second column while some of the

TABLE 4.6-2 - TYPICAL VARIABLES OF INTEREST FOR GRAPHICAL OUTPUTS

INDEPENDENT VARIABLES	MAJOR DEPENDENT VARIABLES	DEPENDENT VARIABLES SUBSETS
Life Cycle Phase		Allocated
Equipment Class	MTBF	Specified
Use Environment	MTTR	Demonstrated
Design Approach/Technology		Prod. Verified
Part Quality Level	Cost	Field Oper.
(Part Derating Practice)		R&D Cost
Complexity		Field Dormant
R Program Provisions		Ratios i.e.
R Program Effectiveness		Pred/Demo.
Testing Provisions		Pred/Field
Fault Tolerance		
BIT Methodology		Prod. Cost
Contract Type		Support Cost
Design Date		
Operating Period		

specifications or dependent variable subsets are listed in the last column.

A typical output would appear as shown in Figure 4.6-2. Generally, the user would specify the independent and dependent variable of interest. He may elect, in addition, to specify which other dependent variables to hold constant. Those not specified would be ignored in the file search (treated as if they did not exist). Thus the plot would contain a data point for each system (equipment) meeting the search specification and its location determined by the specific values of its dependent and independent variables.

Graphical outputs of this type would be useful in presenting summary data in standard RCM output publications. No specific representations are suggested at this time as the usefulness of any given plot will be contingent upon the accumulated data base at the time.

4.6.5 Special Studies

The existence of a large systems/equipment data base represented by the RCM presents the opportunity to perform special studies to verify, improve, and develop both qualitative and quantitative techniques which will advance the general level of R&M capabilities. These studies may be structured by either the RCM staff or the RCM user. The open-ended nature of this type of technical service makes it impossible to exhaust the examples which can be suggested by these activities which might include:

1) Improved prediction by function.

2) Design to cost analysis.

3) Review of lessons learned data.

4) Identification of weak R&M areas.

5) Hypothesis testing.

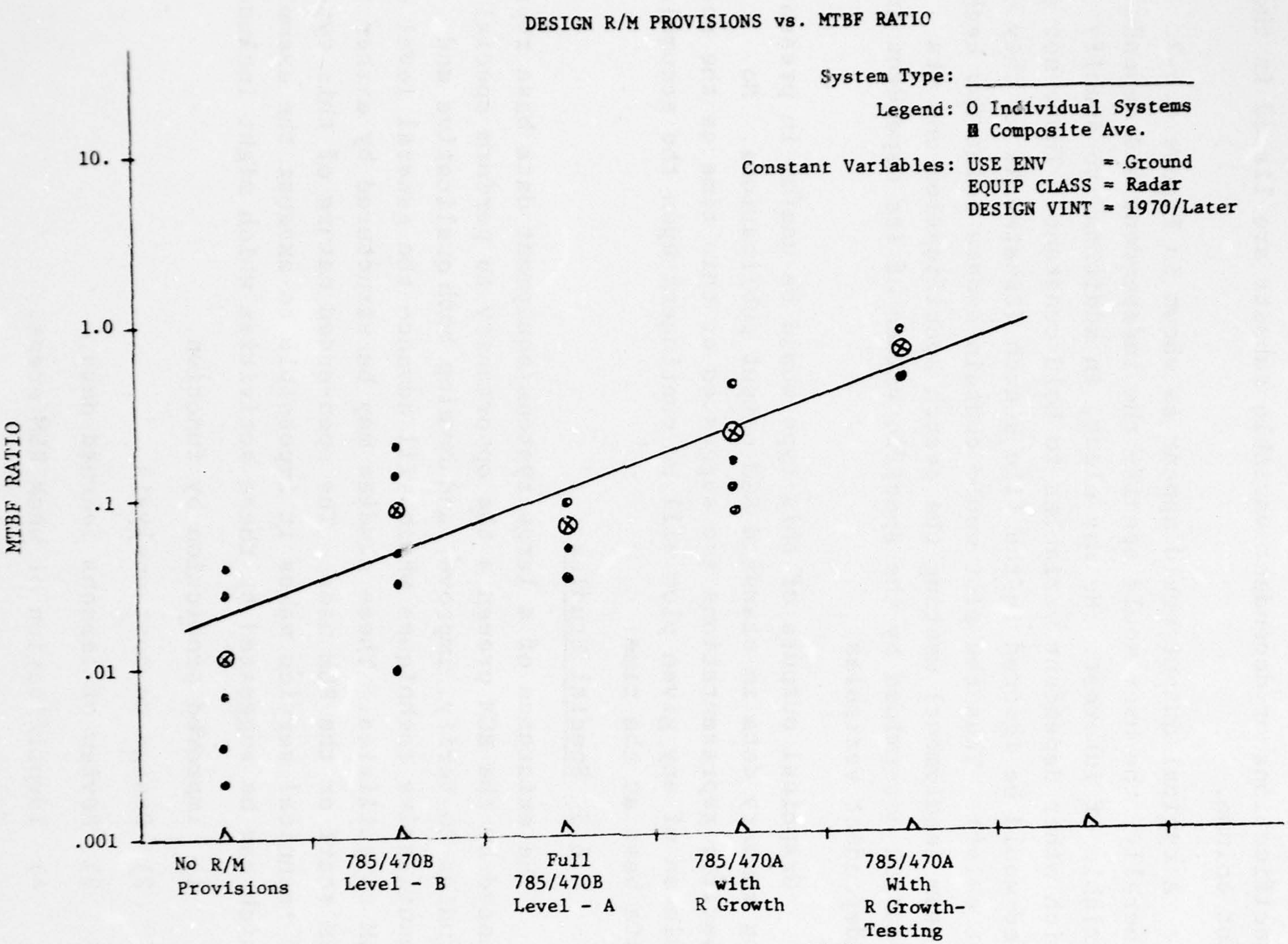


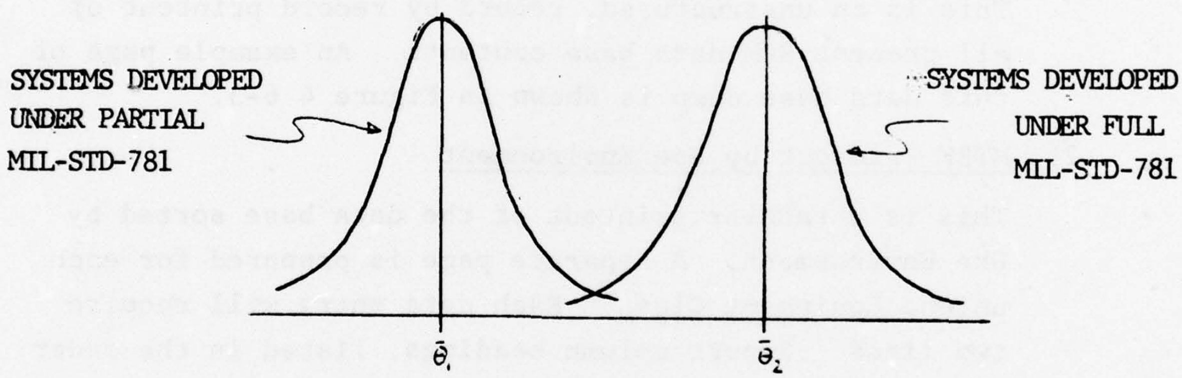
FIGURE 4.6-2 EXAMPLE GRAPHICAL OUTPUT

6) Evaluation of R&M program effectiveness.

A typical technique, involving hypothesis testing in evaluating the effect of procedural items (e.g., MIL-STD-781 on R&M performance) could consist of the following procedure:

1) Null Hypothesis: H_o - there is no essential difference between the fielded performance of systems developed under partial MIL-STD-781 and full MIL-STD-781

2) Method: Construct two distributions of performance data and test for significant statistical difference between population means θ_1 and θ_2 using students t test.



3) Result: Accept <u>or</u> reject H_o on basis of t test

a) to accept H_o implies that partial application of MIL-STD-781 during development is as effective as full application of MIL-STD-781

4) Implications: Can impact development costs -- trade off studies can now follow to balance MTBF and development cost.

4.6.6 Demonstrational Outputs

During the study program, a small data base of 'live' data collected from a number of different sources was entered into the computer files. To demonstrate the feasibility of using the automated data management capability, several reports were generated from this data base and are included in a separate bound data base document which is the "Hard Copy Reliability Memory" required by the contract SOW. The demonstrational output includes:

1) RCM Data Base Printout

This is an unstructured, record by record printout of all present RCM data base contents. An example page of this data base dump is shown in Figure 4.6-3.

2) MTBF Printout by Use Environment

This is a tabular printout of the data base sorted by Use Environment. A separate page is prepared for each unique Equipment Class. Each data entry will require two lines. Report column headings, listed in the order they appear across the page are:

1st Line: Use Environment
Design Year
Nomenclature
Part Quality
Part Derating
Data Source
MTBF Value

2nd Line: Fault Tolerance
Development Testing

Data entries within each Equipment Class will be sorted on the first three fields (Use Environment, Design Year and Nomenclature). Entry values for Fault Tolerance and Development Testing being descriptive in form requires about 45 column spaces each. An example is shown in Figure 4.6-4.

3) Direct Queries

The data base was exercised against ten unique queries, eight of which resulted in the location of equipment in the data base with the unique search specification. Three examples of search specifications are given as follows:

a) IF: Equipment Category = Computer
AND: Use Environment = Aircraft
PRINT OUT: System Nomenclature
Part Derating
MTBF Value
Data Source
System Parameters

b) IF: Param = BIT Effectiveness
PRINT OUT: Nomenclature
Fault Detection Mode
Fault Isolation Mode
Extent of BIT
BIT Methodology

c) IF: Fault Detection = Offline
AND: BIT Implementation = Hardwired
PRINT OUT: Equipment Category
Use Environment
Design Year
Numeric
Parameter

Each query results in a report output providing a listing of the specified field values for each data record on file meeting the search specification.

```
00101UHF RADIO SET                    AN/ARC-164       MAGNAVOX
0010278 CHANNEL AIRBORNE UHF COMMUNICATIONS
00103F33657-74-0545        3UHF RADIO SET          AN/ARC-164
00104MAGNAVOX              720302730408751026711794           232232   11
00105COMPETITIVE DEVELOP CONTRACT F33657-73-0192 AGAINST OTHER CONTRACTOR
00107 1   2      1111111     1    122     1
001081                       11 1000
00199WEIGHT               LBS.   17.3
00199NO. OF MODULES               1.
00199HEIGHT               IN.    4.75
00199WIDTH                IN.    5.0
00199DEPTH                IN.    9.5
00199POWER CONSUMPTIONWATTS 110.
00199CHANNELS                    7000
00201UHF RADIO SET                    AN/ARC-164       MAGNAVOX
0020270 CHANNEL AIRBORNE UHF COMMUNICATIONS
00203F33657-74-0545        3UHF RADIO SET          AN/ARC-164
00204MAGNAVOX              720302730408751026711794           232232   11
00205COMPETITIVE DEVELOP CONTRACT F33657-73-0192 AGAINST OTHER CONTRACTOR
00207 1   2      1111111     1    122     1
002081                       13      10.0 MIN
00299WEIGHT               LBS.   17.3
00299DEPTH             IN.       9.5
00299NO. OF MODULES               1.
00299HEIGHT               IN.    4.75
00299WIDTH                IN.    5.0
00299POWER CONSUMPTIONWATTS 110.
00299CHANNELS                    7000
00301UHF RADIO SET                    AN/ARC-164       MAGNAVOX
0030270 CHANNEL AIRBORNE UHF COMMUNICATIONS
00303F33657-74-0545        3UHF RADIO SET          AN/ARC-164
00304MAGNAVOX              720302730408751026711794           232232   11
00305COMPETITIVE DEVELOP CONTRACT F33657-73-0192 AGAINST OTHER CONTRACTOR
00307 1   2      1111111     1    122     1
003081                       5       20.0MIN
00399WEIGHT               LBS.   17.3
00399NO. OF MODULES               1.
00399HEIGHT               IN.    4.75
00399WIDTH                IN.    5.0
00399DEPTH                IN.    9.5
00399POWER CONSUMPTIONWATTS 110.
00399CHANNELS                    7000
00401UHF RADIO SET                    AN/ARC-164       MAGNAVOX
0040270 CHANNEL AIRBORNE UHF COMMUNICATIONS
00403F33657-74-0545        3UHF RADIO SET          AN/ARC-164
00404MAGNAVOX              720302730408751026711794           232232   11
00405COMPETITIVE DEVELOP CONTRACT F33657-73-0192 AGAINST OTHER CONTRACTOR
00407 1   2      1111111     1    122     1
00408                        14      45.0MIN
00499WEIGHT               LBS.   17.3
00499NO. OF MODULES               1.
00499HEIGHT               IN.    4.75
```

FIGURE 4.6-3 EXAMPLE DATA BASE RECORD PRINT OUT

```
                                EQUIPMENT CATEGORY

                                      COML

USE ENV     DES YR     EQUIPMENT NOMENCLATURE      PART DERAT    DATA SOURCE              MTBF
=======     ======     ========================    ==========    ===========              ====
A7C           72       UHF RADIO SET               2             3                       26542
FAULT TOLER:                   NONE          DVLPT TEST:DES QUAL  ENVL QUAL R GRWTH COMPET


USE ENV     DES YR     EQUIPMENT NOMENCLATURE      PART DERAT    DATA SOURCE              MTBF
=======     ======     ========================    ==========    ===========              ====
A7C           72       UHF RADIO SET               2             3                       16546
FAULT TOLER:                   NONE          DVLPT TEST:DES QUAL  ENVL QUAL R GRWTH COMPET


USE ENV     DES YR     EQUIPMENT NOMENCLATURE      PART DERAT    DATA SOURCE              MTBF
=======     ======     ========================    ==========    ===========              ====
A7C           72       UHF RADIO SET               2             3                        3004
FAULT TOLER:                   NONE          DVLPT TEST:DES QUAL  ENVL QUAL R GRWTH COMPET


USE ENV     DES YR     EQUIPMENT NOMENCLATURE      PART DERAT    DATA SOURCE              MTBF
=======     ======     ========================    ==========    ===========              ====
A7C           72       UHF RADIO SET               2             3                        1655
FAULT TOLER:                   NONE          DVLPT TEST:DES QUAL  ENVL QUAL R GRWTH COMPET
```

FIGURE 4.6-4 EXAMPLE EQUIPMENT CATEGORY SORT

5 RCM MANAGEMENT

The management plan covering the establishment and operation of the RCM is presented in this section. Functional and service milestone schedules, organizational structure, and staffing and physical facility estimates cover the initial five year period beginning with implementation of this plan.

The plan recognizes the value of an orderly evolution of RCM functions and services with attendant expansion of staff and physical facilities. The plan is further predicated on the assumption that the RCM will become a part of the department of the existing Reliability Analysis Center, a DOD information analysis center.

5.1 Five Year Master Schedule

The recommended overall milestone schedule for the RCM is shown in Figure 5.1-1. This schedule is based on the conditions and assumptions stated above and describes the major effort, achievements and milestones that must be accomplished to bring the RCM to full effectiveness in serving its designated user community.

During the 5-year period the RCM will pass through several distinct phases, each emphasizing a specific area of concern as follows:

Phase I - Data Collection and Reduction

Phase II - RCM Implementation

Phase III - Service Capability Augmentation

Phase IV - Full Operational Status

There is some time overlap between the several phases as evident in Figure 5.1-1. It is appropriate to point out that these phase distinctions do not imply that only the indicated

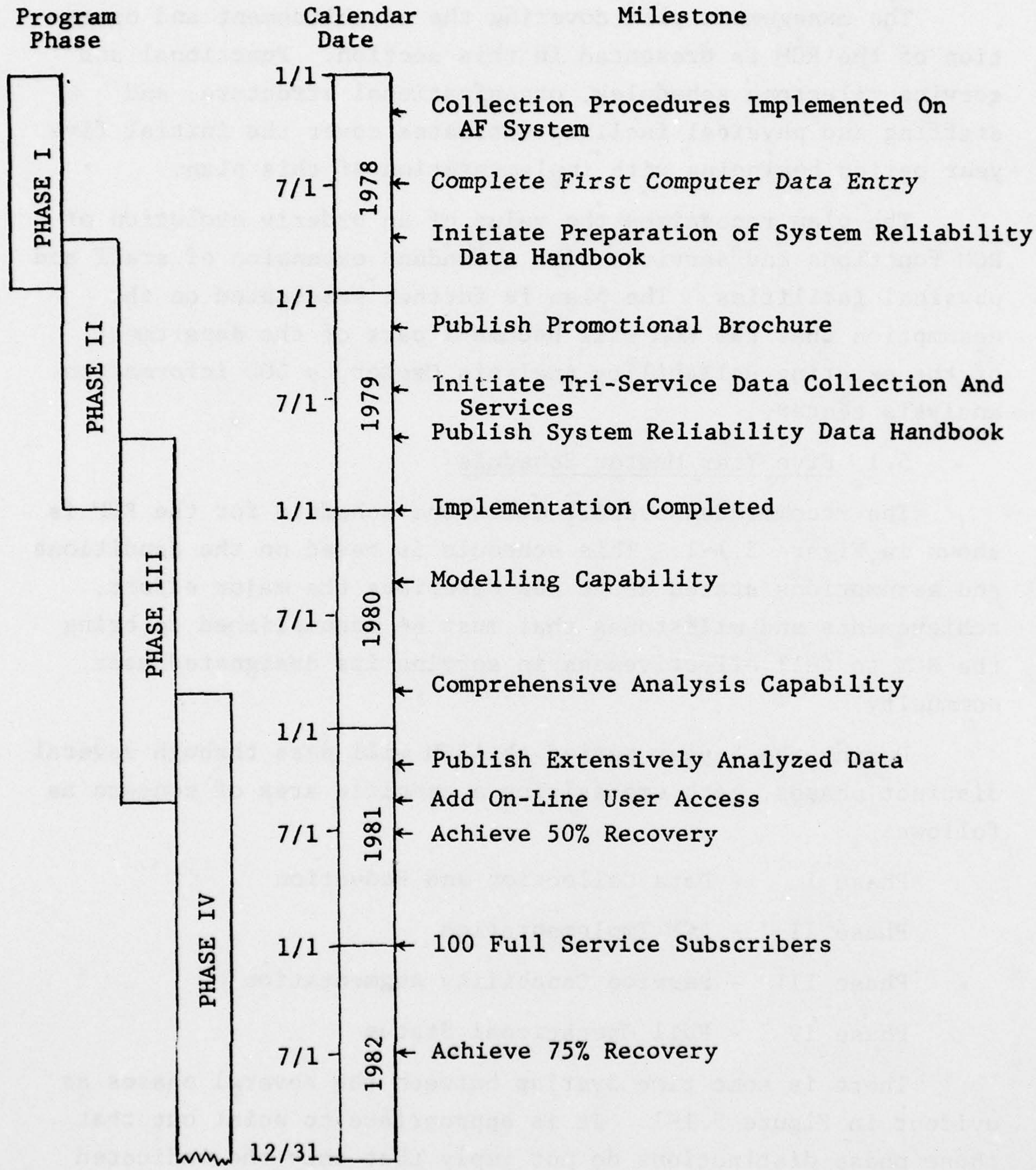


FIGURE 5.1-1 FIVE YEAR MILESTONE SCHEDULE

activity will be pursued during each phase. Rather, efforts will be directed toward the establishment of RCM functions and servicing user needs from the very beginning. However, the plan recognizes that unless specific actions are planned and budgeted for the stated milestone, schedules may be jeopardized.

Some of the major activities expected during each phase are described in the following.

5.1.1 Data Collection and Reduction (Phase I)

During this phase, effort would concentrate on identifying sources, pursuing data collection and finalization of computer file (library) system. Further, data reduction procedures will be prepared and implemented on collected data.

Data collection effort would concentrate on fielded military systems with the intent being to catalog a full life cycle memory on a meaningful number of systems. Of particular concern would be acquisition of cost data and other unpublished operational data and subjective information necessary to provide a meaningful "Corporate Memory".

The present data summary forms would be refined to assure completeness and compatibility with the computerized data system, and converted to computer data file structures and input encoding forms. As resources permit, data will be reduced, summarized and entered into computer files. This effort would serve as a mechanism to test and debug the entry system as well as result in a "live" data base.

Finally, consideration would be given to a review of planned outputs. The intent of this effort is to determine more specifically the outputs that can be supported by the early data base. It is anticipated that preparation of an Electronic System Reliability Data Handbook would be initiated during this phase.

5.1.2 RCM Implementation (Phase II)

During Phase II the full spectrum of IAC functions would be implemented. Basically, this consists of routinizing the inputting and file maintenance functions so they are performed in a "production" manner. More importantly other functions would be established including preparation of standard output products, processing of user inquiries and requests for consulting assistance. User charge policy and service plans would be instituted along with promotional plans and order processing procedures. It is envisioned that the RCM would become a part of the Reliability Analysis Center. Common functions might include data collection from SPO offices and operating commands, computer data entry and file maintenance, promotion, administration of user service records, order processing, etc.

5.1.3 Service Capability Augmentation (Phase III)

In addition to continuing RCM functions emphasis during this period would be placed on expanding and extending RCM output products and service capabilities. Of major importance would be exploitation of data resources for correlation studies, analyses, and other sophisticated statistical analysis which would produce reliability models and answers to plaguing problems. Among these might be: evaluation of environmental K factors; prediction by system function and characteristics models; reliability influence of reliability control elements; field reliability vs. predicted - influence of system and reliability control program factors, etc. These efforts would lead to enhancement of RCM credibility and value to the user community by making analyzed data available which has been until now badly needed but essentially unobtainable on a broad scale.

5.1.4 Full Operational Status (Phase IV)

During this fourth phase, the RCM would reach full operational status. That is, all functions and services could now be performed on a routine basis using stabilized, fully documented methods and procedures. However, it does not preclude an ongoing review of policies, functions, outputs, and services which are essential management tasks to assure that the RCM will remain abreast of latest developments and responsive to changing user needs.

In a fully operational state, the major contribution of RCM is envisioned in the area of special studies and investigations where its accumulated data resources would enable indepth insight into problems that have plagued system reliability engineers and program managers for many years.

5.2 Organization

Appropriately structuring a data analysis center presents a unique challenge. A large segment of the staff are professionals trained to perform in an R&D environment. Most of the work will be along these lines, yet an operating center is somewhat analogous to a manufacturing concern.

In order to assure timely entry of latest information into the files, as well as timely dissemination of knowledge to users, strict attention to "production-control" concepts is required. This means that much of the staff, including professionals, are operating as "production" employees with major emphasis on maintaining efficiency, schedules and quality control. The analogy extends further: individuals must work cooperatively together toward a common goal of producing an output product, as contrasted to rather independent activities characteristic of R & D laboratories. Finally, a data analysis center does require an R & D function to develop new methods, capabilities and products.

These characteristics require not only that the center be organizationally structured to foster cooperative, efficient interchange but that staff members be selected for their ability to perform in this environment.

The conceptual organization of Figure 5.2-1 is recommended as the basic structure of the RCM. The organization is functionally oriented. Separate groups are responsible for each of the major functional areas. There are two line functions, namely; Technical Operations and Information Processing which would comprise the bulk of the RCM staff. These are further separated into subgroups, again determined by the major function they are expected to perform.

Capabilities Development (R&D) and Administrative Services are service functions whose primary purpose is to support the operating staff and Technical Director.

The staff complement of each group and subgroup is contingent upon the resources available for operating the RCM. During early stages, many functions may be part time such that one individual would perform several.

Two key elements essential for achieving successful data analysis center are implicit in this recommended structure.

1.) Each organizational group contains an appropriate mix of professionals (i.e. reliability engineers, computer scientists, information specialists) to assure that they can communicate and cooperate with one another, and,

2.) All technical policies and decisions are made by professionally trained and experienced electronic systems reliability engineers. During conduct of a particular investigation, and for preparation of an output product, the engineer in charge must assume full responsibility for all technical decisions.

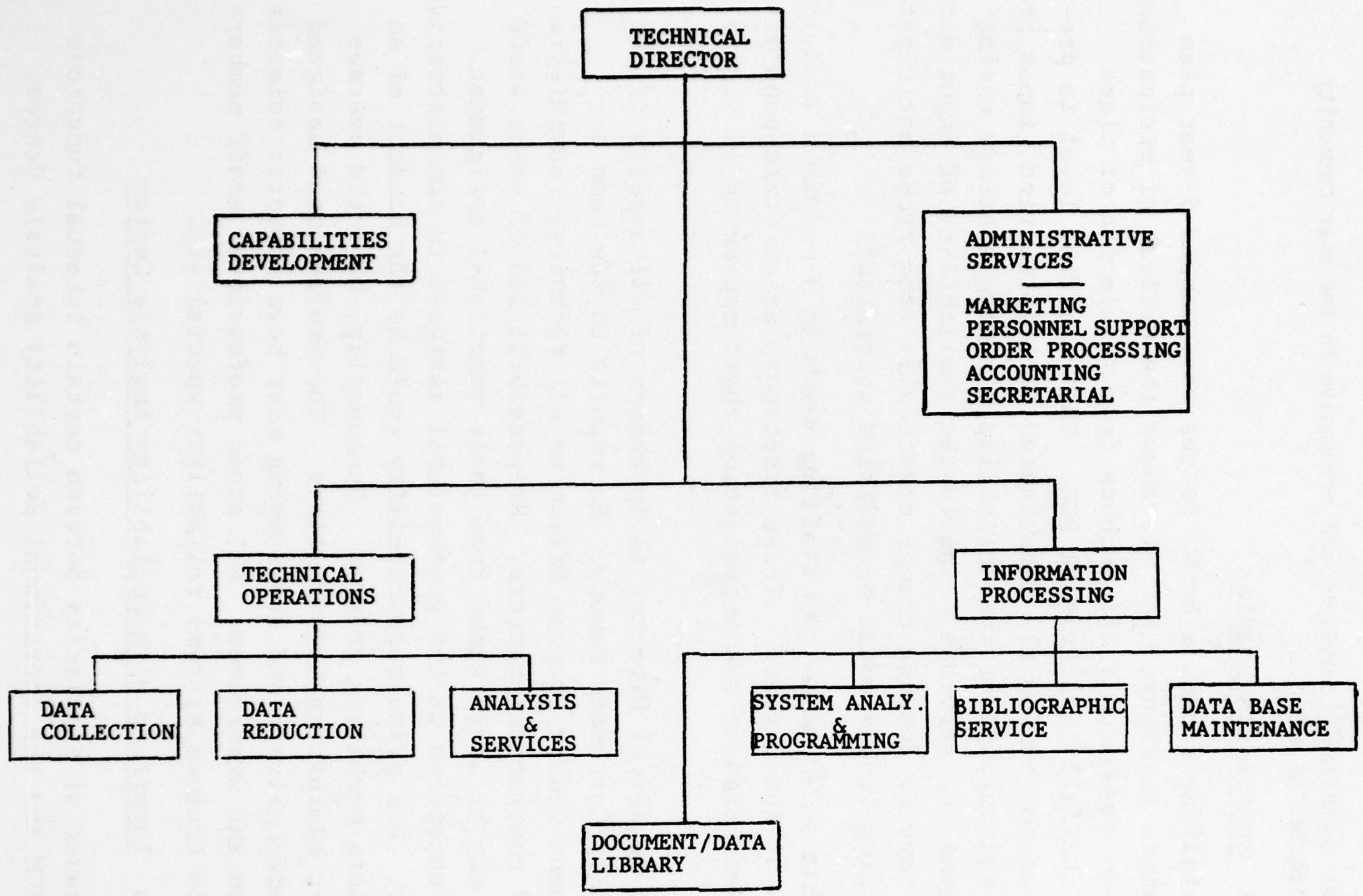


FIGURE 5.2-1 CONCEPTUAL RCM ORGANIZATION

These criteria are considered critical to assure that the RCM remains technically competent and responsive to the user community it is designated to serve.

5.3 Staffing Schedules

A staffing schedule based on the recommended 5-year plan is presented in Figure 5.3-1. It shows the buildup of professional and semi-professional staff members from initiation of plans through the fully operational RCM. This staffing level is predecated on performing all anticipated data collection, input processing and output/service activities assuming a steady rising user demand for services. Should the availability of input data or user service demands change drastically from those anticipated, the staffing levels would be modified accordingly.

Table 5.3-1 shows the staffing needs by functional assignment for each of the 5 years. These functional areas correspond with those identified on the organization chart appearing in Figure 5.2-1.

The Technical Director is in charge of all aspects of the Reliability Corporate Memory. He reports to the Rome Air Development Center Program Office on all technical, administrative and contractual matters. Responsibilities of other staff members may be ascertained from their functional assignment. The one exception is the professional assigned to Administrative Services. His prime responsibility would be the conduct of an appropriate marketing program. Secondarily, he would oversee the other administrative functions. The professional assigned to Systems Analysis and Programming must have computer sciences education and experience. All other professional staff members should be trained systems reliability specialists.

5.4 Interface With Reliability Analysis Center

Because of similarity between certain internal functions of the RCM and the operational Reliability Analysis Center,

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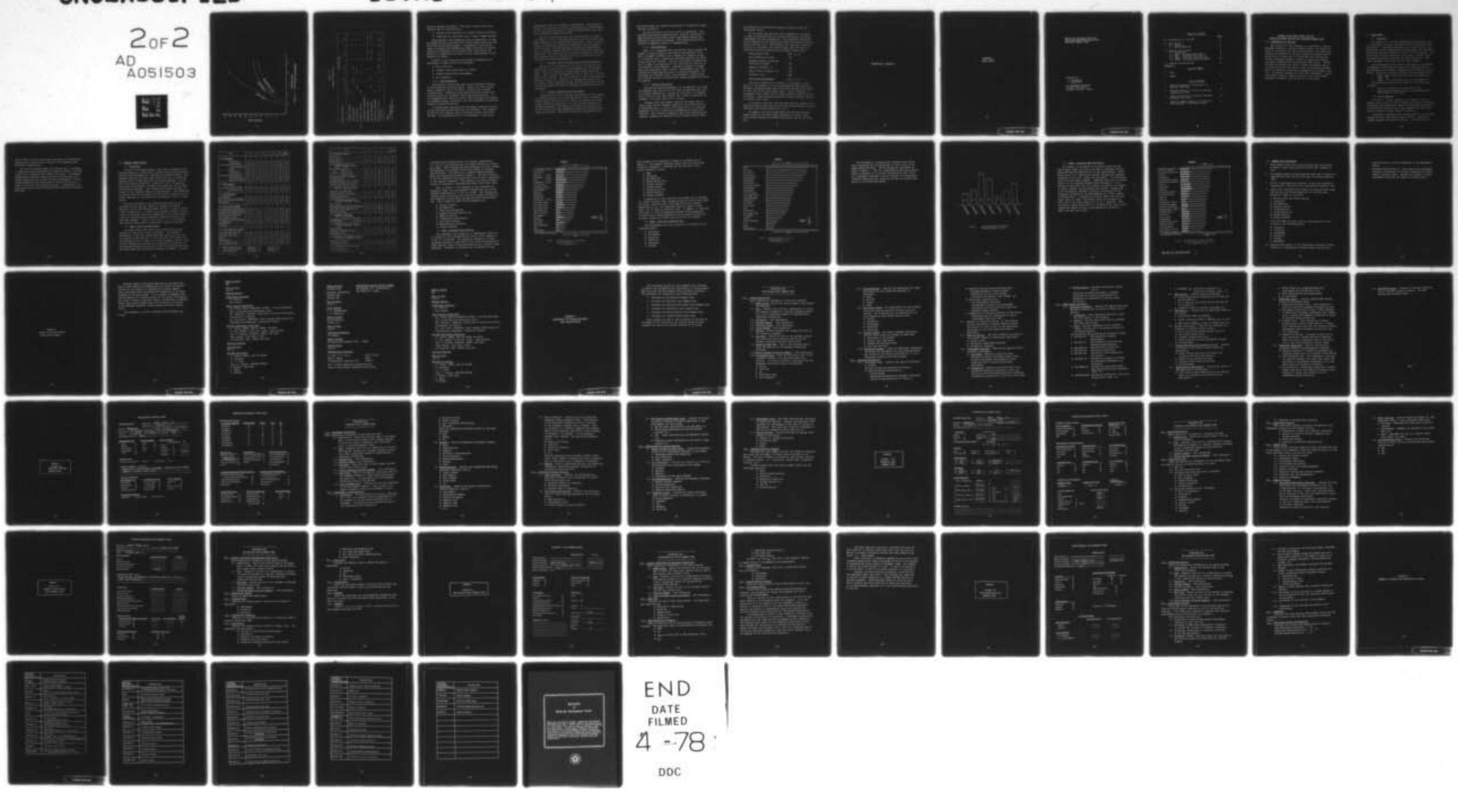

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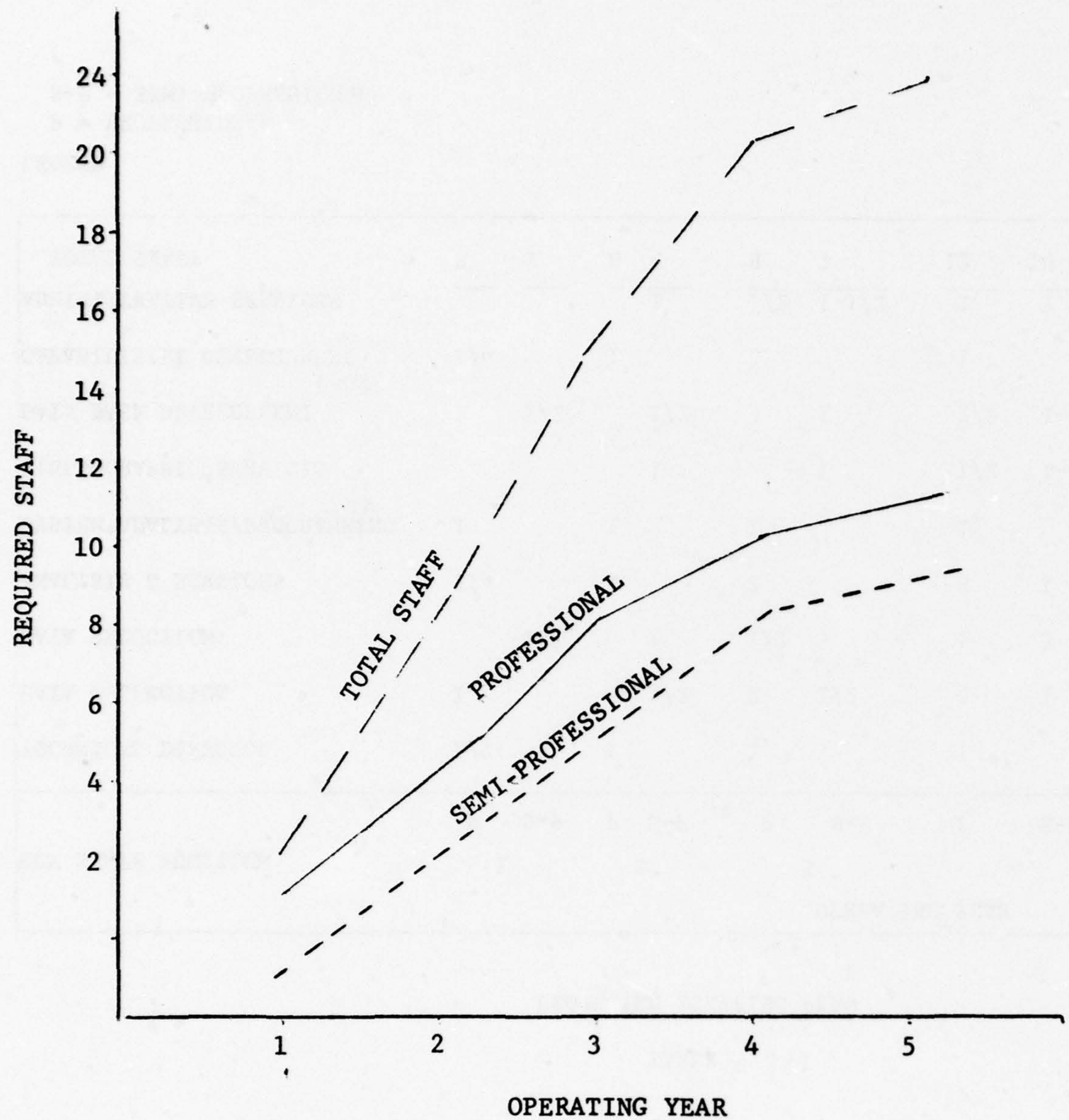

FIGURE 5.3-1 RCM STAFFING REQUIREMENTS

TABLE 5.3-1

PROJECTED STAFFING PLAN

RCM STAFF FUNCTION	OPERATING YEAR 1		2		3		4		5	
	P	S-P	P	S-P	P	S-P	P	S-P	P	S-P
TECHNICAL DIRECTOR	1/2		1		1		1		1	
DATA COLLECTION	1		2	1/2	2	1/2	3	1	3	1
DATA REDUCTION		1/2		1	1/2	3	1	3	1	4
ANALYSIS & SERVICES	1/4		1		2		3	1	4	1
SYSTEM ANALYSIS/PROGRAMMING	1		1		1		1		1	
BIBLIOGRAPHIC SERVICES				1		1	1/2	1-1/2	1/2	1-1/2
DATA BASE DEVELOPMENT		1/2		1/2		1	1/2	1-1/2	1/2	1-1/2
CAPABILITIES DEVELOPMENT	1/4		1		2		1		1	
ADMINISTRATIVE SERVICES				1	1/2	1-1/2	1	2	1	2
TOTAL STAFF	3	1	6	4	9	7	12	10	13	11

LEGEND

P = PROFESSIONAL
S-P = SEMI-PROFESSIONAL

resource sharing is possible. The areas in which interactive functions may be considered are:

1) Sharing staff personnel for closely related activities

2) Combining the activities into a single, common function

While benefits from commonality may be appreciable, it must be recognized that each center has its own unique objectives and particular operating procedures. Consequently, care must be taken in planning and implementing common activities to prevent arbitrary intermingling of functions which could negate the benefits of commonality and reduce overall effectiveness of the separate operations.

Several of the activities which might be candidates for performing in common include the following:

- data collection
- document input processing and library
- computer applications programming
- user awareness

5.4.1 Data Collection

The RCM will utilize many data sources presently accessed by the Reliability Analysis Center. Whereas the latter seeks data on component parts, the RCM is concerned with systems configurations, technology associated reliability control program and system (or equipment level) R&M characteristics. It is recommended that data from those sources dealing with systems or equipment design, production, test and deployment be collected using an integrated approach.

A unified input specification requirement should be devised so that both RCM and RAC needs will be satisfied. The responsibility for this combined data solicitation should reside with the RCM. Its engineering staff is knowledgable in electronic

system functional and reliability technologies. These specialists will be qualified to assess qualitatively the effectiveness of the associated reliability control program which is an important information element of the RCM.

Once the system level data are collected, with the necessary detail, it can be reduced internally into the separate elements required by the RCM and RAC respectively. While a certain amount of preliminary reduction (determining system/equipment operating hours, applied operating stresses and environments, etc.) is common, separate detailed reduction processes should be maintained. With this approach, personnel trained for each specific purpose would be assigned resulting in high quality summary data and maximum productivity.

5.4.2 Document Input Processing and Library Maintenance

Because of the difference in the types of documents categorized and their end use, it is recommended that the library keep a clear-cut distinction between RCM and RAC source documents. This includes the physical facility itself and all document control records. Yet the mechanics of input processing and document storage are expected to be sufficiently uniform such that they could be performed within the same functional activity by the same persons as long as reasonable supervisory control is exercised.

5.4.3 Computer Applications Programming

Responsibility for maintenance and extension of the computer software system used by the RCM and RAC can be assumed by a common organizational activity. These are computer and information processing specialists with good working knowledge of the RADC Honeywell 5180 computer and operating system as well as the several data base management systems and software languages used thereon. Application programs are generated and

maintained under the direction and control of reliability engineering specialists.

The one difficulty that could arise is scheduling. With separated functional responsibilities, conflicts may arise in negotiating priorities when several individuals require preparation of applications programs. This eventuality would be covered by management policy at implementation.

5.4.4 User Awareness

While it is recognized that the RCM will have a unique complement of output products and services and, therefore, will serve a somewhat different user community as compared to RAC, it is believed that a common user awareness function can effectively serve both centers. The key to achieving a satisfactory rate of usage is recognition of the center and its services by the potential using community. Because of changes in assignments and engineering staff turnover, announcements and other information dispersing means must be repeated frequently. By utilizing the available talent and resources for publicizing the combined services of RCM and RAC, maximum recognition should be achieved.

5.4.5 Physical Facilities

The physical space requirements of the RCM will, of course, be dependent upon the size of its staff, accumulated data, and its service capabilities. During the first year, for example, with a total of four staff members and a small accumulation of documents, its space needs will be minimal.

Assuming each staff member requires 100 square feet of office space and the document collection can be maintained in an equivalent area, a total of 500 square feet or a room with dimensions of 20 X 25 feet would accommodate the entire RCM function. This estimate presupposes that other administrative, computer terminal and reproduction and related services would

be provided by the Reliability Analysis Center or Rome Air Development Center.

By the fifth year when the staff complement is estimated to reach 13 professionals and 11 semi-professionals, the space requirements are more substantive. The following listing provides estimates for the anticipated staff and related activities during the fifth year. The estimates are based on a space allocation of 100 square feet and 64 square feet for each professional and semi-professional staff member respectively:

Professional Staff	1300	sq. ft.
Semi-Professional Staff	700	
Document Library (Including Classified Storage)	200	
Computer Terminals (3)	200	
Output Stock, Shipping, etc.	120	
Corridors, etc.	620	
TOTAL SPACE REQUIREMENT	3,140	sq. ft.

The space allocated for corridors is contingent to some extent on the geometry of the area provided for RCM operations. The above estimate assumes that aisles and corridors will amount to about 25% of the total usable space. This is based on a rectangular floor layout with a single corridor between two rows of offices. Other configurations would require different amounts of unusable floor space.

It should be noted that the five-year spacing estimate still does not allow for reproduction and other special purpose equipment (drafting, specialized typewriters, etc.).

In summary, the space requirements for RCM will be quite modest during its initial stages and expand in concert with staff growth reaching an estimate 3140 square feet by the fifth year.

APPENDICES A THROUGH D

APPENDIX A
USERS SURVEY

REPORT ON THE USER SURVEY FOR THE SYSTEM/EQUIPMENT RELIABILITY CORPORATE MEMORY (RCM)

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REPORT ON THE USER SURVEY FOR THE
SYSTEM/EQUIPMENT RELIABILITY CORPORATE MEMORY (RCM)

1.0 INTRODUCTION TO THE RCM

The objective of this program is to establish a "system/ Equipment Reliability Corporate Memory (RCM)", the purpose of which is to provide data and information that will enable comparisons and benefits of various reliability program control activities to be made and to provide data for refining prediction techniques leading to improved correlation between predited-to-demonstrated-to-operational MTBF ratios. Further, the RCM will provide cost data to foster development and application of design and analysis tools for producing hardware with cost effective operations performances at a minimal total cost. The RCM is designed such that when implemented, it will continuously compile, analyze and report life cycle system/ equipment reliability and reliability related data.

2.0 USER SURVEY

2.1 Objective

The objective of the User Needs/Data Sources Survey task is to determine the types and nature of data required by major user groups. A secondary objective was to ascertain the characteristics of data generated during procurement and deployment of military systems and means by which it can be acquired. The survey task is being conducted in two parts, a letter survey and indepth personal interviews with key individuals. This report documents the results of the letter survey.

The questionnaire form used for this survey is reproduced in Appendix A along with the cover letter which was sent to the respondents to provide a background and foundation for the survey. The survey questions covered two areas dealing with:

1. DATA - data collection activities of prospective users, and
2. USAGE - the utilization level of the repository.

Two additional questions were asked in the survey questionnaire:

1. Are you interested in an RCM Center, and
2. Would you be willing to share your R&M experience as an input to the Center?

2.2 Survey Approach

The survey is being conducted in two parts; the first being a letter survey to obtain general information concerning prospective user information needs and input data availability and identify a smaller group of key organizations which will then be visited to obtain indepth information.

Originally respondents were chosen primarily as Air Force program directors and system project officers, contractor program managers and logistic officers. As conducted, the

letter survey covered a much larger sampling and included R&M specialists in other military services, and contractor and industrial organizations.

The set of questions under the category DATA is intended to assess the future availability of data for input to the RCM as well as to determine data needs of the users. For example, organizations required to make reliability predictions of a system design will (1) require realistic methodology; (2) procedural guidelines and (3) historical failure rate data in order to carry out the predictive process. Subsequently, the prediction results will be documented and represents potential RCM input.

3.0 GENERAL SURVEY RESULT

3.1 Discussion

A total of 363 questionnaires were sent to industrial and military agencies to assess their interest and the corresponding need for the development of a Reliability Corporate Memory. Two hundred twenty two of these forms (61%) were sent to industrial agencies and 141 (39%) were sent to military agencies. At the end of the survey cutoff date, January 14, 1977, 71 questionnaires had been returned, 46 (65%) from industrial and 25 (35%) from military agencies. This represented a sample of about 20 percent of the original number of questionnaires. The proportion of returns from both the industrial and military populations was almost identical to that which was distributed to each of these groups.

The data contained in the returned questionnaires were extracted and the absolute number of responses for those questions in both the DATA and USAGE sections is shown in Tables 1 and 2 respectively. In Table 1 all possible response combinations are tabulated since each combination can be interpreted as a form of the past-present-projected scenario associated with each data category. Table 2 lists the A, B, C, or D response only because these items are essentially mutually exclusive.

3.2 DATA - Projected Data Needs

To assess future data needs three answers (A,B,C) were possible to each type of data requirement. The response determined if that data category had been previously used (A), is currently being used (B), or will be used in the future (C). Any combination of A, B and C is a valid response, however, only certain combinations provide the interpretations necessary to discriminate between those who will constitute the future market for these items and the relative frequency of demand. In order

DATA		A	B	C	AB	AC	BC	ABC	No Reply
1(a) R&M PROGRAM									
MIL-STD-785	Prediction	9	11	0	4	3	0	31	13
	Design Review	8	10	1	4	1	0	31	16
	Failure Analysis	4	11	2	4	3	0	30	17
	FMEA	14	8	1	4	3	0	30	11
MIL-STD-470	Prediction	14	6	2	2	1	0	21	25
	Design Review	15	8	2	2	1	0	19	24
	Maintainability	9	8	4	3	1	1	18	28
	Design Tradeoffs	8	8	4	3	1	1	18	28
1(b) PARTS CONTROL									
MIL-STD-965	Control (PCB)	12	5	6	3	1	1	12	31
	Advisory (PAG)	6	1	5	1	1	1	6	50
1(c) R&M PREDICTION									
MIL-HDBK-2178		8	12	0	3	6	1	27	14
RADC Non-Electronic Handbook		8	6	7	4	1	0	11	34
MIL-HDBK-472		9	5	3	4	3	0	33	34
1(d) R&M TESTING PROGRAM									
R Demonstration (MIL-STD-781)		13	6	5	2	8	1	20	16
Combined Environmental/R Test		5	4	8	1	0	0	5	48
Forced Defects Production		3	1	4	1	1	1	3	57
R Acceptance Testing		7	5	9	3	4	1	8	34
M Demonstration (MIL-STD-471)		13	4	5	1	10	0	11	27
Environmental		6	2	3	1	3	0	12	44
R Growth									
1(e) COST ANALYSIS & CONTROL									
Life Cycle Costing (LCC)		9	7	6	0	4	1	17	27
Design to Cost (DTC)		7	7	7	1	2	2	12	33
DTUPC		2	2	4	0	0	1	7	55
Cost Modeling		7	6	5	0	1	1	15	37
Cost Tradeoff Studies		8	5	1	2	2	2	18	33

2 PHASES FOR WHICH LIFE CYCLE R&M AND COST DATA IS BEING RETAINED	Conceptual: 15 Validation: 19 Development: 40	Production: 32 Storage: 10 Deployment: 11

TABLE 1

USAGE	A	B	C	D	No Response
1(a) SYSTEMS & FEEDBACK					
Predicted R	4	6	31	14	16
Demonstrated R	2	6	35	15	13
Operational R	2	6	29	19	15
1(b) COMPARISON & BENEFITS OF VARIOUS R PROGRAM ACTIVITIES					
MIL-STD-785 Provisions	2	6	30	10	23
Part Selection — Quality Levels	4	9	30	12	16
Part Selection — Screening Tests	4	10	31	12	14
Production R Control Techniques	3	6	27	11	24
R Growth Testing	2	6	27	13	23
Assembly/Equipment Level Screening	2	7	27	12	23
Combined Environmental/R Testing	2	5	28	13	23
1(c) DEVELOPING AND/OR REFINING R MODELING & PREDICTION TECH.					
Inherent R (MIL-HDBK-217B)	3	9	26	14	19
Operation & Maint. Degradation	3	6	34	16	12
Production Degradation	1	5	27	13	25
1(d) DETERMINING EFFECTIVENESS OF R DESIGN & IMPROVEMENT CONCEPTS					
Parts (TX/ER)	3	9	27	13	19
Parts Application, Derating, Redundancy	1	13	28	13	16
Operations & Maintenance Factors	2	6	28	13	22
Production Factors	1	7	27	11	25
1(e) DETERMINE DESIGN/COST TRADEOFF EFFECTIVENESS					
Predicted-to-Demonstrated To-Operational — MTBF Ratio	2	11	29	14	15
Predicted-to-Demonstrated To-Operational — MTTR Ratio	5	9	29	12	16
1(f) DETERMINING THE EFFECTIVENESS OF M DESIGN & IMPROVEMENT CONCEPTS					
Design Factors	4	10	29	16	12
Operation & Maintenance Factors	4	8	25	16	18
Production Factors	3	6	27	12	23
1(g) DETERMINE EFFECTIVENESS OF NEW AIR FORCE ACQUIS. MANAGEMENT CONCEPTS					
Design to Cost (DTC)	2	7	27	9	26
Life Cycle Cost (LCC)	2	5	29	10	25
1(h) COMPARISON OF COST FORECASTED					
vs Actual Acquisition	2	3	24	10	32
vs Actual Maintenance Support	2	3	25	11	30

to provide that interpretation, the response combinations, B, C, BC, AC, and ABC were used as strong indicators of future data needs. These combinations were tabulated for each category and expressed as a percent of the total number of returned questionnaires. The result was a relative demand frequency which was ordered and plotted in Figure 1. The heavy portion of the bar indicates the proportion of the military contribution to the response frequency. This appears to be fairly uniform across all categories, accounting for about 15% in most cases.

Thus, in Figure 1, the frequency is the cumulative percentage of times that the respondent indicated any one of the response combinations B, C, BC, AC, or ABC. The response percentage varies from about 15% to 65% with roughly one-third of the categories falling above 40% and one-third falling below 40%. Those categories above the 40% responses are:

- Failure analysis
- MIL-HDBK-217B
- Prediction MIL-STD-785
- Design Review MIL-STD-745 (M)
- FMEA MIL-STD-785
- R Demonstrated MIL-STD-781
- Life Cycle Costing
- Maintainability Analysis
- Design tradeoffs

3.3 <u>DATA - Estimated Availability</u>

The responses, both singly and in combination, which are of interest to this interpretation consist of the sequence A, B, AB, AC, BC and ABC. The cumulative tabulation of these responses provides an indication of the relative frequency for which specific types of data have been and are currently being generated. Frequency of response were calculated for each

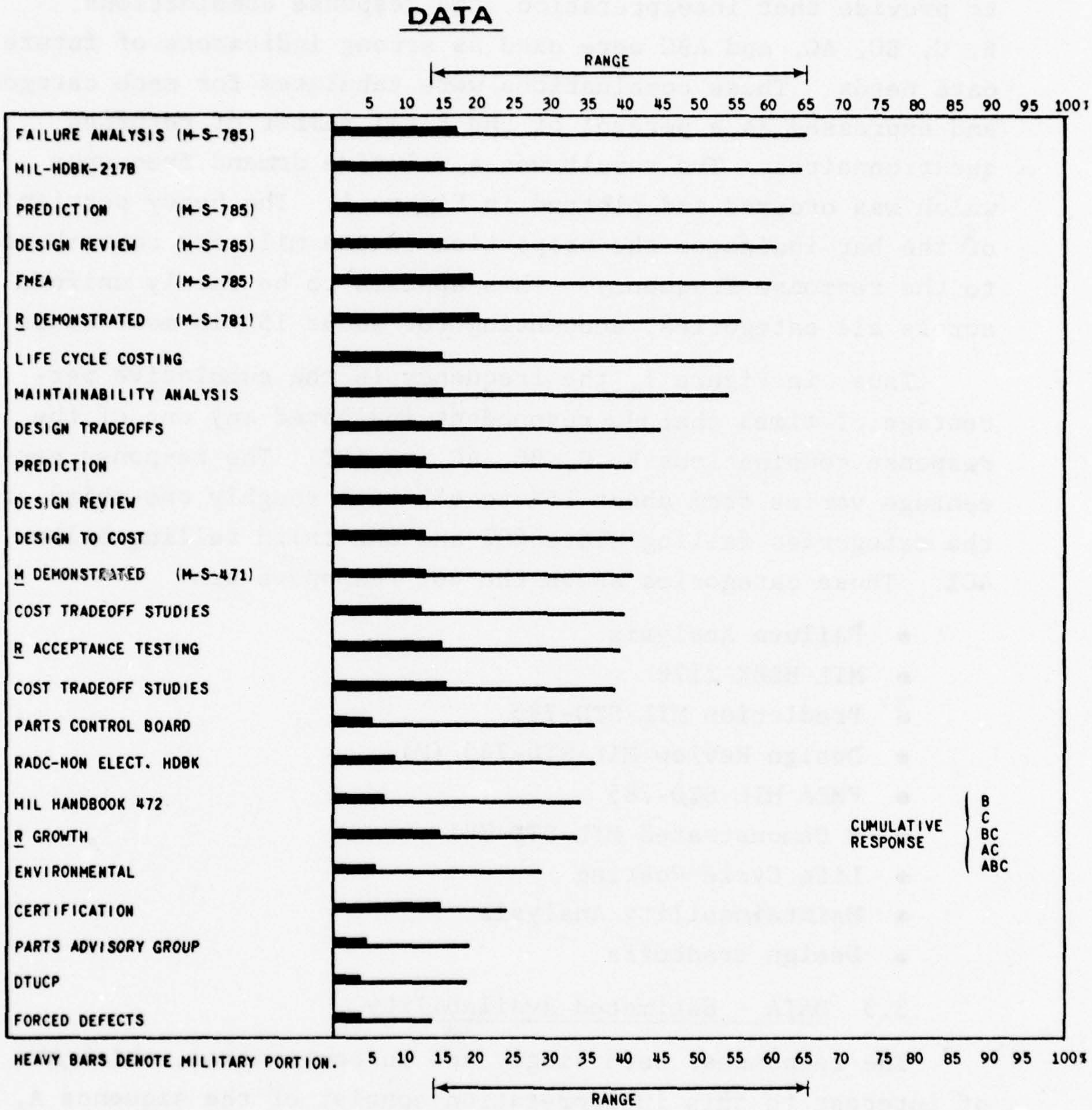

Figure 1 RELATIVE FREQUENCY FOR PERFORMANCE OF SPECIFIC R&M TASKS (ALL RESPONDENTS71/363)

data category and sequentially ordered for presentation in Figure 2. The response frequency ranges from 15 to about 85% across all categories. Choosing the top one-third of the listed categories we have:

- FMEA
- Prediction
- MIL-HDBK-217B
- Design Review (R)*
- Failure Analysis
- R Demonstrated
- Design Review (M)
- Maintainability
- Design tradeoff

A comparison of this list with the similar list in Section 3.2, which indicates those categories where projected data needs will exist, indicates that with exception of one category - Design Review (R) - the remaining items are common to both lists, but in slightly different order. It appears, as expected, that there is close correspondence between those categories in which data is being generated and the estimated projection of those categories in which there will be a data demand.

3.4 DATA - Life Cycle R&M Cost Data

System/Equipment Life Cycle evolution is described by the following phases:

- Conceptual
- Development
- Validation
- Production
- Deployment
- Storage

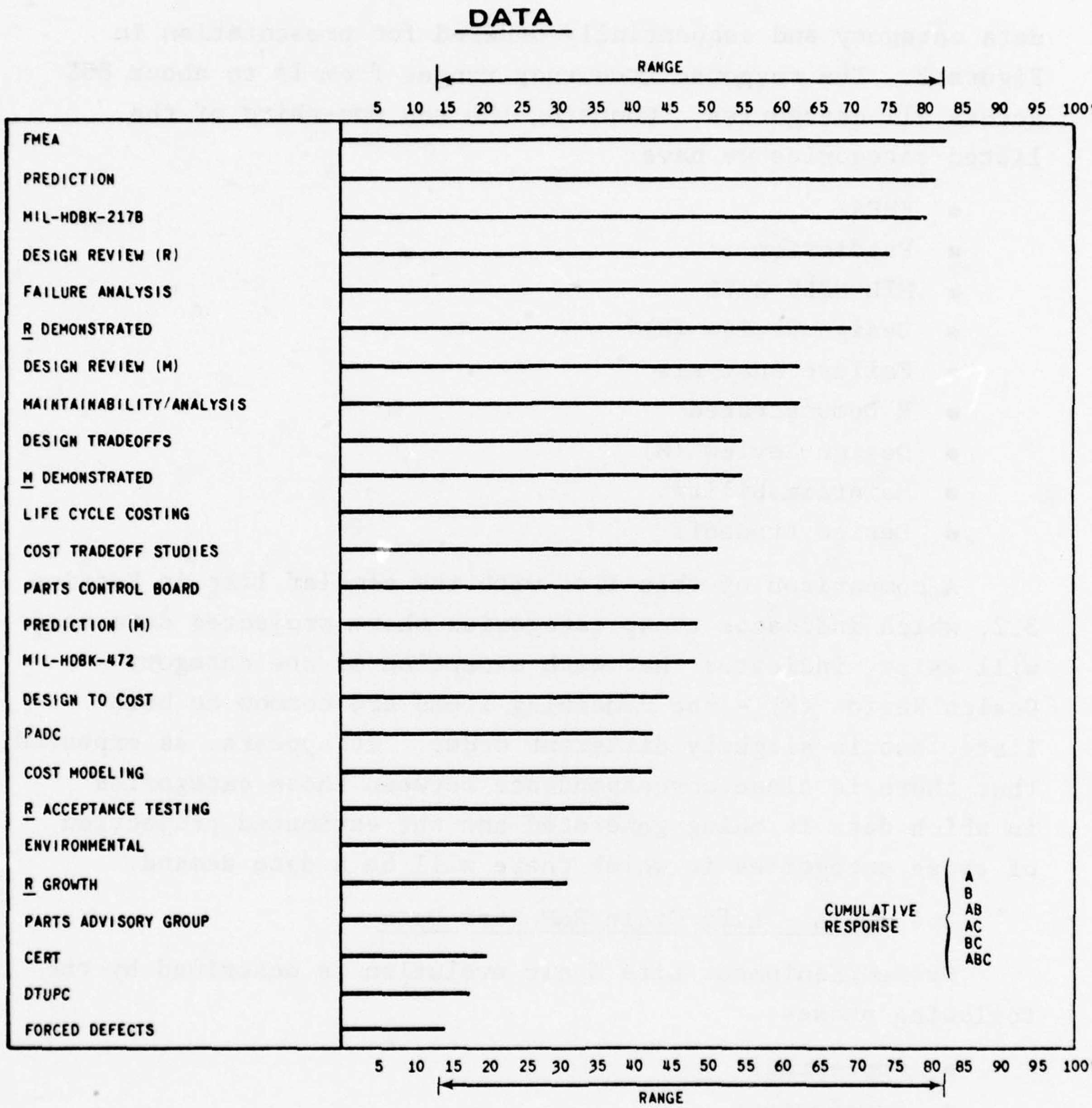

Figure 2 RELATIVE FREQUENCY OF PAST AND CURRENT GENERATION OF DATA (ALL RESPONDENTS 71/363)

The assessment of response data indicated that 63% of those responding are collecting data in one or more of the phases mentioned above. The percentage for each phase is shown in Figure 3. This is a significantly positive response which is enhanced by the further determination that 77% of all respondents expressed a direct interest in a Reliability Corporate Memory and were generally willing to provide information to an established Center.

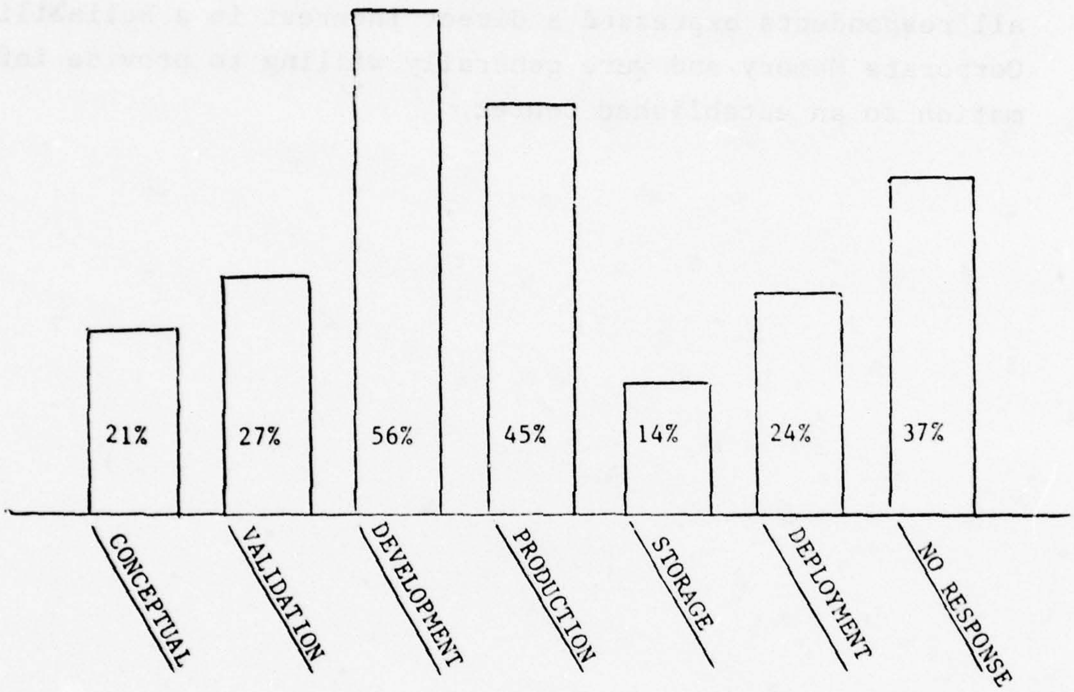

Figure 3 PHASE DISTRIBUTION OF RETAINED SYSTEMS/EQUIPMENT COST DATA

3.5 USAGE - Projected RCM Utilization

An estimate of the degree of utilization which an RCM Center might expect to receive was made by reviewing the data recovered from the USAGE portion of the questionnaire. Utilization which is of significant interest included the combined responses of daily (A), weekly (B) and monthly (C) utilization levels for each usage category. Compiling these data as before results in the frequency diagram shown in Figure 4. It is obvious by inspection that the relative utilization by category is almost uniform, varying between 40% and 60%. Roughly 50% of the respondents therefore indicate a utilization of all categories mentioned in the questionnaire on a daily, weekly, or monthly basis. A separate calculation shows that of these three levels of usage, the monthly level (C) accounted for about 75% of the total number of A, B, or C responses. Thus the greater demand would exist on a monthly level, with a still significant number of users interrogating the system on a weekly and even daily basis.

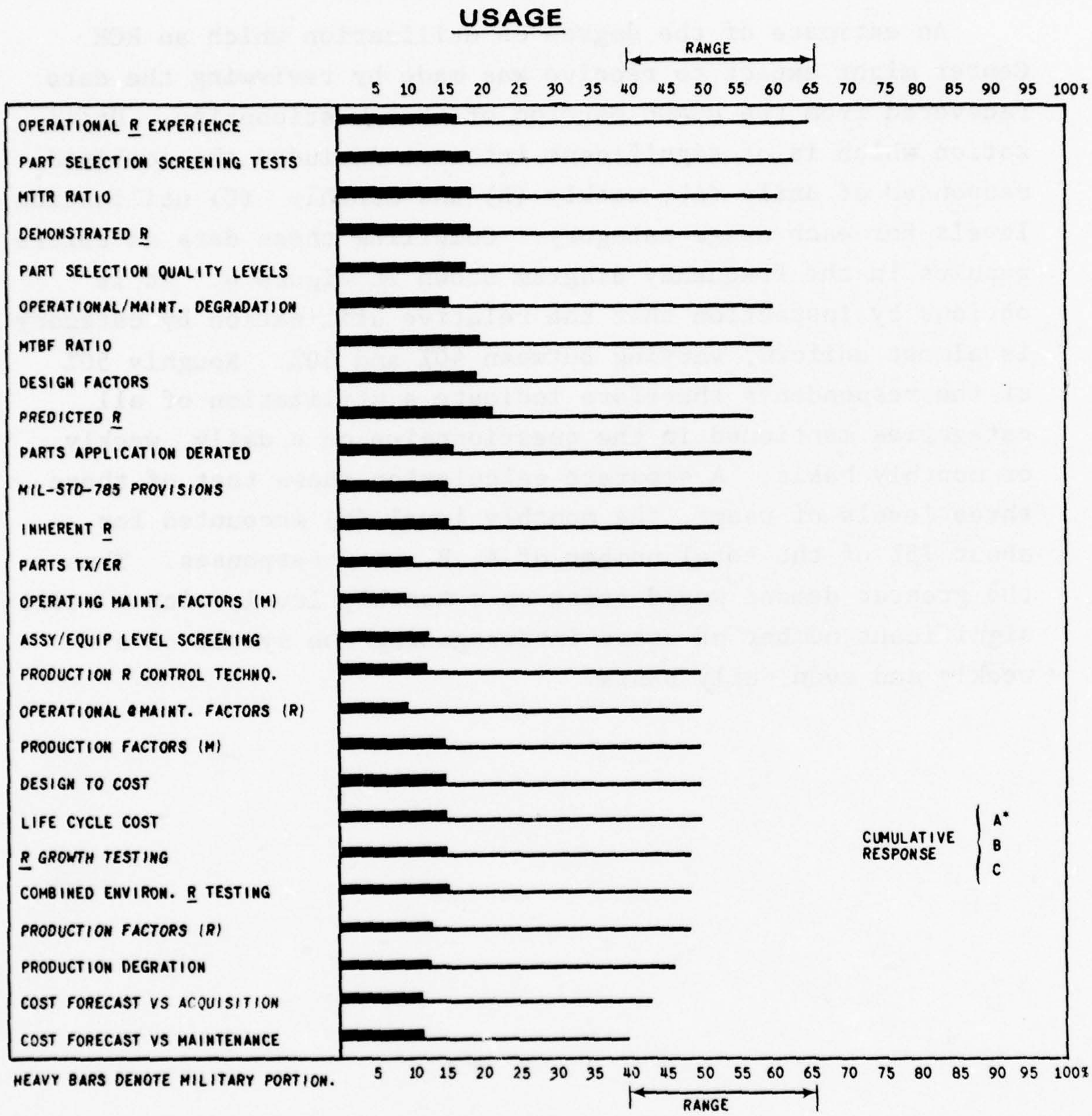

Figure 4 RELATIVE DEMAND FREQUENCY OF USAGE FOR EACH CATEGORY OF RCM DATA PRODUCTS (ALL RESPONDENTS 71/363)

APPROXIMATELY 75% OF THE CUMULATIVE RESPONSE IS MONTHLY USAGE; 25% IS DAILY AND WEEKLY USAGE.

4.0 SUMMARY AND CONCLUSIONS

1. Three-hundred sixty three questionnaires were distributed, of which 71 were returned by the cutoff date, January 14, 1977.

2. Two hundred twenty two questionnaires were sent to industrial organizations (61%) and 141 were sent to military agencies (39%).

3. Of the 71 questionnaires returned, 46 were from industrial organizations (65%) and 25 were from military agencies (35%).

4. Twenty-five categories were studied for projected data needs, and the task and current generation of data and those categories common to both were;

   - Failure modes and Effect Analysis
   - Prediction
   - MIL-HDBK-217B
   - Failure Analysis
   - R Demonstrated
   - Design Review (M)
   - Maintainability
   - Design Tradeoff

5. Life Cycle R&M cost data; 63% are collecting data in one or more of the following phases;

   - Conceptual
   - Validation
   - Development
   - Production
   - Storage
   - Deployment

6. Seventy-seven percent of all respondents expressed a direct interest in a Reliability Corporate Memory and were gen-

erally willing to provide information to an established Center.

7. Projected RCM Utilization - About 50% of the respondents indicate a utilization of all data categories on a daily, weekly or monthly basis. Seventy-five percent of these respondents indicated the usage on a monthly level.

APPENDIX B

PERSONAL VISITS WITH POTENTIAL USERS AND DATA SOURCES

Personal visits to potential data sources and users were made to open channels of communication and assess the general reaction to the concept of a Reliability Corporate Memory. These discussions were encouraging and supportive of the ideas presented by the RCM concept. It is strongly recommended that similar agendas are included as part of the initial RCM development phase to focus on specific outputs, availability of desired output data, means by which data can be accessed, the nature of the RCM/USER interface, service charges and other salient topics.

This appendix is a list of agencies and individuals contacted.

Agency Visited

ESD

Date of Visit

3/17/77

Morning Meeting

Individuals Contacted

- Mr. DeMilia
- Major Burner

Other Contacts Identified

- Col. Murray Edwards AFALD/AOE (WPAFB) - has R&M background and is concerned with maintenance costs
- Col. Schlosser, SAMSO/AW, Directorate of Acquisition Support (counterpart of DeMilia)
- Col. Phil Jeter, SAMSO/AWS, Chief Systems Effectiveness Div. (configuration management, Reliability Branch)

SPO R&M Individuals Identified

- Lt. Carter, AWACS, Code YW (MITRE, 261-2346)
- B. Gray, RACALS, X-4147 (Mr. Spang - same program)
- Capt. Ed Johnson, AFSATCOM, (MITRE, 261-2360)
- Frank Doherty, Pave Paws, X-4002
- Irv Bosinoff, 481B, (MITRE, 261-2459)

Afternoon Meeting

Date of Visit

3/17/77

SPO R&M Individuals

- Lt. Carter, AWACS, Code YW (MITRE)
- S. Greenberg
- Lt. J. Jolly
- Capt. E. Johnson, AFSATCOM (MITRE)
- F. Doherty, Pave Paws
- D. Spang
- M. Zymaris

<u>Agency Visited</u>

Raytheon Corp.

Equipment Systems Div.
Wayland Labs
Wayland, MA

<u>Individuals Visited (Title & Phone)</u>

Don Harrady, Mgr. of Reliability
(617/358-2721 X-2691)

<u>Date of Visit</u>

3/17/77

<u>Visit Made By</u>

H. A. Lauffenburger
J. R. Wingfield

<u>Agency Visited</u>

Martin-Marietta
Orlando, FL

<u>Date of Visit</u>

2/24/77

<u>Individual Contacted</u>

Tom Gagnier

<u>Agency Visited</u>

AF Acquisition Logistics Div. - WPAFB

<u>Date of Visit</u>

2/16/77

<u>Individual(s) Contacted</u>

Lt. Col. B. M. Ellis	(PTO) X-53147
Fred M. Maass	(PTO)
AF Acquisition Logistics Div.	(AFALD)

PTO = Product Evaluation Engineering Test
Ellis is with Product Evaluation Directorate

Agency Visited

ESD

Date of Visit

3/17/77

Morning Meeting

Individuals Contacted

- Mr. DeMilia
- Major Burner

Other Contacts Identified

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- D. Spang
- M. Zymaris

APPENDIX C
PROCEDURES FOR SYSTEMS/EQUIPMENT DATA TRANSCRIPTION

The procedures outlined in this appendix were developed to explain and standardize the transcription of systems/equipment data onto the Data Summary Forms previously discussed. The procedures are presented in the following order:

1. Procedure for Program Data Summary Form
2. Procedure for Technical Data Summary Form
3. Procedure for Financial and Support Data Summary Form
4. Procedure for Reliability Data Summary Form
5. Procedure for Maintainability Data Summary Form
6. Procedure for Program Effectiveness Form

With exception of item 6, each procedure is followed by an example of that portion of the form set which has been completed for one of the systems reviewed in this study.

PROCEDURE FOR R&M PROGRAM DATA SUMMARY FORM

1.0 System Description

Enter appropriate information in the space provided.

1.1 Nomenclature: Record the official name of the contracted equipment.

1.2 Type: Normally this will be a combination of letters and numerals arranged in a specific sequence providing a short significant method of identification. (Reference MIL-STD-196).

1.3 Contractor: Self explanatory

1.4 Contract Number: Self explanatory

1.5 Procuring Agency: Self explanatory

1.6 Using Command: Self explanatory

1.7 Mission: Briefly describe the intended function of the referenced equipment.

1.8 Data Date: Record the date of the document containing the earliest data and also the date of the document containing the most current data.

1.9 Design Vintage Year: This is the calendar year in which the majority of the equipment design was performed.

1.10 Source Document Accession Numbers: Self explanatory

1.11 Procurement Level: Note the functional level of the equipment hardware to be delivered under this contract. It should be noted in accordance with the equipment definitions found in MIL-STD-280.

- System
- Subsystem
- Set
- Functional Group
- Unit/Component

1.12 Use Environment: Indicate the operational end usage environment for the contracted equipment as applicable.

- Space
- Aircraft
- Ground
- Other

1.13 Life Cycle Phases: All applicable life cycle phases associated with the specific contract should be checked. The scheduled date of implementation of each respective phase should also be noted.

- Concept
- Validation
- Development
- Production
- Deployment

1.14 Mission Length: The normal equipment operational mission length should be checked as applicable.

- Continuous or not defined
- Greater than eight hours
- Between one and eight hours
- Less than one hour

1.15 Historical Summary: Enter any additional information concerning the equipments life cycle R&M provisions not covered by the contract specified in 1.0 (i.e., additional contracts and their purpose).

2.0 Contract Description

2.1 Procurement Type: Indicate the type of procurement to be made.

The four options are described as follows:

- Existing System characteristics
  - Proven Design
  - Engineering Documentation Package in Existence
  - Extensive Requalification Noc Required

- Modified Existing System characteristics
  - Minimum Redesign to Achieve Specfic
  - Maximum Use of the Proven Design
  - Customized Performance, Size, Weight, etc.
- New Design characteristics
  - All Requirements Specified
  - Configuration Controlled by Government
  - Reliability and Test Activities Monitored
  - Logistic Support Assured
- Combination of Existing, Modified or New System
  - Characteristics for Combination of These Procurement Types will Vary

2.2 Reliability Financial Posture: If the contract contains Reliability Financial Incentive Awards, this should be noted as well as the approximate percentage of the total budget allocated to Reliability.

2.3 Type of Contract: The basic financial structure of the contract should be indicated as applicable.

- Design to Cost
- Reliability Improvement Warranty
- Reliability Incentive

2.4 Procurement Approach: Identify the approach used in equipment procurement.

- Low Bidder: (Minimize Acquisition Cost) Contractor develops procurement using lowest possible development and production costs consistent with a specified functional performance.
- Minimum LCC: (Minimize Total Life Cycle Cost) Contractor develops procurement to most cost effective reliability/maintainability parameters as defined by solution to a life cycle cost model.

- Minimum Support: (Minimize Maintenance Support Costs)
  Contractor develops procurement to highest obtainability reliability/maintainability parameters as permissible by present state-of-the-art.

3.0 R&M Program Provisions

3.1 Applicable Documents: Identify all R&M specification documents required and the extent to which each is employed.

- Contractual - Full compliance required to each and every detail of the document.
- Limited - Specific deviations from the document are stated and allowed.
- Guide - Specific compliance is not required; however, actions are to be patterned after the referenced document.

The applicable R&M specification documents include:

• MIL-STD-470	Maintainability Program Requirements
• MIL-STD-471	Maintainability Verification/ Demonstration/Evaluation
• MIL-HDBK-472	Maintainability Prediction
• MIL-STD-756	Reliability Prediction
• MIL-STD-781	Reliability Tests Exponential Distribution
• MIL-STD-785	Reliability Program for Systems and Equipment Development and Production
• MIL-HDBK-217	Reliability Stress and Failure Rate Data for Electronic Equipment (Sept. 74)
• RADC Notebook	Reliability Prediction - Piece Part Failure Rates (Sept. 67)

- MIL-HDBK-217B Reliability Prediction of Electronic Equipment (Sept. 74)

3.2 R&M Analysis: Indicate analysis performed.

- R and M Analysis and Prediction per MIL-STD-756 and MIL-HDBK-472.
- R or M Analysis and Prediction per MIL-STD-756 or MIL-HDBK-472.
- Informal R and/or M Analysis and Prediction

3.3 R&M Numerics: Indicate how the applicable numerics are stated:

- Contractural MTBF and MTTR/M_{ct}
- Either Contractual MTBF or MTTR/M_{ct} but not both.
- MTBF and/or MTTR/M_{ct} stated as design goal only

3.4 Design Surveillance: Indicate the frequency and formality of required design reviews.

- Two or more Formal Design Reviews required
- One Formal Design Review
- Informal Design Reviews only
- Formal Reliability Growth Management Program
- No Requirement

3.5 Failure Reporting and Corrective Action: Indicate the extent of the required failure reporting procedure(s).

- Formal Failure Reporting and Closed Loop Corrective Action System Required
- Formal Failure Reporting System
- Informal Failure Reporting System
- No Requirement

3.6 Demonstration Requirements: Indicate the extent of R&M demonstration requirements.

- Both formal R and M Demonstration Test Requirements in accordance with MIL-STD-781 and MIL-STD-471

- Either Formal R or M Demonstration Test requirements per MIL-STD-781 or 471
- Other Demonstration Test Requirements
- No requirement

3.7 Development Tests: Indicate required R&M testing during the development phase.

- Design Qualification Tests - Tests designed to show that specified equipment parameters are met
- Environment Qualification Tests - Tests designed to demonstrate equipment performance after subjection to induced environmental conditions as would be expected during fielded use.
- R Growth Tests - Tests designed to identify problem areas, surface latent defects, or underscore deficiencies such that the corrective action implemented causes incremental R growth as the test progresses.
- Competitive Fly-Off - A program in which two or more contractor's develop and build competing models for direct comparison prior to the selection of the final production contract award.

3.8 Production Inspection: Indicate contractually specified inspection methodology(ies) employed.

- Sampling inspection - Inspection procedures for incoming assembly parts as outlined in MIL-STD-105.
- 100% Acceptance Test - Test designed to show that the specific hardware item under tests meets the functional or performance requirement on an item basis within the production situation.
- R Verification - Abbreviated R demo-test (usually higher risk factor and higher discrimation ratio) designed to assure that inherent R is not compromised during production.

3.9 R&M Effectiveness: Indicate the overall effectiveness of the R&M program in general. (See R&M Program Effectiveness Form).

EXAMPLE

AN/ARC-164
COMPLETED PROGRAM
SUMMARY FORM

PROGRAM DATA SUMMARY FORM

SYSTEM DESCRIPTION: Nomenclature UHF Radio Set

Identification No. AN/ARC - 164

Contractor Magnavox Contract No. F 33657 - 74 - 0545

Mission Function 10 Channel airborne UHF Communications

Data Date: Initial 3/2/73 Current 4/8/75 Design Vintage Yr. 1972

Source Document Acces. Nos. 10267

PROCUREMENT LEVEL

- System [ ]
- Subsystem [ ]
- Functional Group [ ]
- Component/Box [ ]
- Set [x]

USE ENVIRONMENT

- Space [ ]
- A/C [x]
- Ground [ ]
- Other [ ]

LIFE CYCLE PHASES

	Contract Applicable	Date
Concept	[ ]	
Validation	[ ]	
Development	[ ]	
Production	[x]	1-75
Deployment	[ ]	

MISSION LENGTH

Continuous or not Defined [ ] >8 hrs. [ ] 1 hr. to 8 hrs. [x] <1 hr. [ ]

HISTORICAL SUMMARY [ ] (Subsume)

Competitive Development Contract F33657-73-C-0192 Against Collins and RCA.

CONTRACT DESCRIPTION

PROCUREMENT TYPE

- Existing System [ ]
- Modified Existing [ ]
- New Design [x]
- Combination of above [ ]

R FINANCIAL POSTURE

- R Incentive Awards [ ]
- R >5% of Budget [x]
- R <5% of Budget [ ]
- Not Determined [ ]

TYPE OF CONTRACT

- Design to Cost [ ]
- R I W [x]
- Reliability Incentive [ ]
- Fixed Price [ ]

PROCUREMENT APPROACH

Low Bidder [ ] Minimum LCC [x] Minimum Support [ ]

PROGRAM DATA SUMMARY FORM (Page 2)

R&M PROGRAM PROVISIONS

APPLICABLE DOCUMENTS	CONTRACTURAL	LIMITED	GUIDE	N/A
MIL-STD-470	☐	☐	☐	☒
MIL-STD-471	☒	☐	☐	☐
MIL-HDBK-472	☐	☐	☐	☒
MIL-STD-756	☐	☐	☐	☒
MIL-STD-781	☐	☒	☐	☐
MIL-STD-785	☐	☐	☐	☒
MIL-HDBK-217	☐	☐	☐	☒
RADC Notebook	☐	☐	☐	☒
MIL-HDBK-217B	☐	☐	☐	☒

R&M ANALYSIS

- R&M Analysis and Pred. per MIL-STD-757 & MIL-HDBK-472 ☐
- R or M Analysis and Pred. ☐
- Informal Analysis and Pred. ☐
- No Req't ☒

R&M NUMERICS

- Contractural MTBF & MTTR ☒
- Contractural MTBF or MTTR ☐
- MTBF/MTTR Design Goals ☐
- No Req't ☐

DESIGN SURVEILLANCE

- $\geq$ 2 Formal Design Reviews ☐
- 1 Formal Design Review ☐
- Informal Review Only ☐
- Rel. Growth Management ☐
- None Required ☐

FAILURE REPORTING AND CORRECTIVE ACTION

- Formal Failure Reporting and Closed Loop Corrective Action System Required ☒
- Formal Failure Reporting Only ☐
- Informal Failure Reporting Only ☐
- Not Required ☐

DEMONSTRATION REQUIREMENTS

- Formal R&M Demo required per MIL-STD-781 and 471 ☐
- Formal R or M Memo Required ☐
- Other Demo Req'ts ☐
- None Required ☒

DEVELOPMENT TESTS

- Design Qualification ☐
- Environmental Qualification ☐
- R Growth Test ☐
- Competitive Fly-off ☒

PRODUCTION INSPECTION

- Sampling Inspection ☐
- 100% Acceptance Test ☐
- Processing Screening ☐
- Reliability Verification per MIL-STD-781 ☒

R&M EFFECTIVENESS

- High ☐
- Medium ☐
- Low ☐

PROCEDURE FOR TECHNICAL DATA SUMMARY FORM

1.0 Equipment Description

Enter appropriate information in the space provided.

1.1 Nomenclature: Record the official name of the equipment, to which this Technical Data Summary applied. It may be the System, Subsystem, Set, Functional Group or the Unit/Component level.

1.2 Type: Normally this will be a combination of letters and numerals arranged in a specific sequence providing a short significant method of identification. (Reference MIL-STD-196)

1.3 Manufacturer: Self explanatory

1.4 Contract Number: Self explanatory

1.5 Data Date: Record the date of the document containing the most current data.

1.6 Source Document Accession Numbers: Self explanatory

1.7 Data Level: This is the specific functional level of the equipment hardware to which these data entries are applicable. (In accordance with the equipment definitions found in MIL-STD-280)

1.8 Used on/Higher Assy: Indicate the end item identified in the procurement contract. This is usually the highest assembly in which this equipment is used.

2.0 Performance Characteristics

2.1 Criticality: The criticality of a system, subsystem, set., etc., is a measure of the indispensability of an equipment or of the function performed by an equipment. Criticality can be defined from any of the following four(4) standpoints:

- mission critical
- safety critical
- poor reliability (historical)
- high cost

Enter the appropriate Criticality Level in the space provided:

- high
- medium
- low

2.2 Category: Check the appropriate equipment category:

- Radar
- Communications
- Computer
- Electronic Countermeasures
- Controls/Display
- Guidance/Navigation
- Weapons
- Other

2.3 Design Approach: Indicate any significant R&M design approaches employed, such as:

- Single Channel
- Dual Channel
- Multi Channel
- Parity Check
- etc.

2.4 Technology: Identify any special technological features employed, such as:

- Core Memory
- Semiconductor Memory
- Plated Wire Memory
- Magnetic Drum
- Magnetic Tape
- Magnetic Disc
- etc.

2.5 Major Parameters: Indicate the most significant equipment design parameter values. The selection of the applicable parameters will be a function of the equipment category (see 2.2 above). That is, selection of a specific category will uniquely define those parameters applicable to that category of equipment. For example: if the equipment category were computer, the applicable parameters may be:

- Memory Size (words)
- Word Size
- Levels of Interrupt
- Cycle Time
- etc.

Physical parameters such as Weight, Volume, Height, Width, Depth, Number of Modules and Power Consumption will be applicable to all categories of equipment.

2.6 <u>Remarks</u>: Check if applicable and enter any additional information concerning equipment description or performance characteristics.

<u>3.0 Reliability Design Features</u>

3.1 <u>Fault Tolerance</u>: Indicate the methodology(ies) employed to alleviate the consequences of failure. These methodologies are:

- Redundant Channels or Equipment
- Graceful Degradation
- Degraded Modes of Operation

3.2 <u>Part Derating Guidelines</u>: Indicate the applicable level of stress derating employed in this equipment design.

- High Reliability
- Intermediate Level
- Normal Commercial Design Standards

3.3 Part Quality Grade/Screen Class: Indicate the extent of quality assurance provisions applicable to part procurements for this design.

- JAN TXV grade semiconductors and JAN 38510 IC's
- JAN TX grade semiconductors and MIL-STD-883 screened IC's
- JAN grade semiconductors and Hermeticly sealed IC's
- Commercial grade semiconductors and plastic encapsulated IC's

4.0 Maintainability Design Features

4.1 Extent of Built-In-Test (BIT): Indicate the sophistication of BIT technologies employed in this design.

- Performance Monitoring Capability
- Fault Detection
- Fault Isolation

4.2 BIT METHODOLOGY: Indicate the method(s) by which any BIT provisions are controlled in this design.

- Software
- Hardware
- Manually
- Combination of the above methods

4.3 BIT Implementation: Indicate the hardware techniques

- General Purpose Computer
- BIT Microprocessor
- Hardwired BIT Controller
- Manually Read Panel Meters

4.4 Diagnostic Level: Indicate the lowest functional level to which a failure or malfunction is capable of being diagnosed.

- Equipment
- Unit
- Assembly
- Piece Part

4.5 <u>Replacement Level</u>: This data item reflects the degree of modularity employed. Indicate the functional level desirable for replacement in the event of failure or malfunction. This level may or may not correspond to the built-in diagnostic level stated in 4.4.

4.6 <u>Type of Cooling</u>: Indicate the type of cooling incorporated in the design.

- Ambient Air (normal convection)
- Forced Air (fan)
- Liquid
- Other

5.0 Complexity/Active Elements

Estimate the total number of parts, the number of different part types and the number of active devices utilized in this design. (An active element is defined as a device which controls or converts energy, i.e., transistors, vacuum tubes, integrated circuits, etc.)

Further itemize the total active element count into the following categories:

- Tubes
- Discrete Semiconductors
- Hybrid ICs
- Monolithic Linear ICs
- SSI/MSI Digital ICs
- LSI ICs
- Microprocessors

EXAMPLE

AN/ARC - 164
TECHNICAL DATA
SUMMARY FORM

TECHNICAL DATA SUMMARY FORM

EQUIPMENT DESCRIPTION: Nomenclature UHF Radio Set

Identification No. AN/ARC-164

Manufacturer Magnavox Contract No. F33657-74-0545

Data Date: Initial 4-8-75 Current 4-8-75

Source Document Acces. Nos. ________ ________ ________ ________

DATA LEVEL

Subsystem ☐

Equipment ☐

Set ☒

Used on/Higher Assy.

Nomenclature NA.

Identification No. ________

Type NA.

PERFORMANCE CHARACTERISTICS

CRITICALITY

High ☐ Medium ☒ Low ☐

CATEGORY

Radar	☐	Computer	☐	Controls/Displays	☐	Weapons	☐
Communications	☒	ECM/EW	☐	Guidance/Navigation	☐	Other	☐

DESIGN APPROACH

1 ☒ AM	3 ☐ PM	5 ☒ Analog/voice	7 ☐
2 ☐ FM	4 ☐ Pulse	6 ☒ Digital	8 ☐

TECHNOLOGY

1 ☒ UHF	3 ☐ HF	5 ☐ LF	7 ☐ Telephone
2 ☐ VHF	4 ☐ MF	6 ☐ VLF	8 ☐

MAJOR PARAMETERS

1 No. of Channels	7000	11			
2		12			
3 Channel Width	25 KHz	13			
4		14	Weight	(lbs)	17.3
5 Transmitter Power	10 Watts	15	Volume	(cu. ft.)	
6		16	No. of Modules		1
7 Receiver Sensitivity	4 μv	17	Height	(in.)	4.75
8		18	Width	(in.)	5.00
9 Digital Data Rate	19.2 KBPS	19	Depth	(in.)	9.5
10		20	Power Consumption	(watts)	110.

REMARKS ☐(Subsume)

TECHNICAL DATA SUMMARY FORM (Page 2)

RELIABILITY DESIGN FEATURES:

FAULT TOLERANCE		PART DERATING GUIDELINES		PART QUALITY GRADE/ SCREEN CLASS	
Redundant Channel/Equip.	☐	High Rel.	☐	TXV, JAN 38510	☐
Graceful Degradation	☐	Intermediate	☒	TX , 883	☒
Degraded Modes	☐	Normal Commercial	☐	Jan , Hermetic	☐
None	☒			Commercial, Plastic	☐

MAINTAINABILITY DESIGN FEATURES:

EXTENT OF BUILT-IN TEST		BIT METHODOLOGY		BIT IMPLEMENTATION	
Performance Monitoring	☐	Software Controlled	☐	G. P. Computer	☐
Fault Detection	☐	Hardware Controlled	☐	Microprocessor	☐
Fault Isolation	☐	Manual	☐	Hardwired Controller	☐
None	☒	Combination	☐	Panel Meters	☐

DIAGNOSTIC LEVEL		REPLACEMENT LEVEL		TYPE OF COOLING	
Equipment	☐	Equipment	☐	Ambient Air	☒
Unit	☐	Unit	☐	Forced Air	☐
Assy	☒	Assy	☒	Liquid	☐
Part	☐	Part	☐	Other	☐

COMPLEXITY/ACTIVE ELEMENTS:

NUMBER OF PARTS	NUMER OF PART TYPES	NUMBER OF ACTIVE ELEMENTS
2223	115	554

ACTIVE ELEMENT TYPE		ACTIVE ELEMENT COUNT
Tubes		None
Discrete Semiconductors		118
Hybrid ICs		None
Monolithic Linear ICs	}	
SSI/MSI Digital ICs	} 436	
LSI ICs	}	
Microprocessors		None

PROCEDURE FOR FINANCIAL AND SUPPORT DATA SUMMARY FORM

1.0 System Description

Enter appropriate information in the space provided.

1.1 Nomenclature: Record the official name of the contracted equipment.

1.2 Type: Normally this will be a combination of letters and numerals arranged in a specific sequence providing a short significant method of identification. (Reference MIL-STD-196)

1.3 Contract Number: Self explanatory

1.4 Source Document Accession Numbers: Self explanatory

2.0 Acquisition Cost

Enter the appropriate information for the following items and identify them as estimated/proposed or actuals.

2.1 R&D Cost

2.2 Test and Evaluation Cost

2.3 Non-Recurring Production Costs, including:

- First article tests
- Test equipment
- Tooling facilities
- System integration
- Documentation

2.4 Recurring Production Cost, including:

- Parts and materials
- Fabrication
- Assembly
- Manufacturing support
- Quality control
- Testing
- Packaging
- Shipping

2.5 Quantity of systems/items procurred.

3.0 Acquisition Factors

Where applicable include a narrative description of any significant acquisition cost factors such as:

- Competition or other cost-reduction incentives
- Relation to state-of-the-art (components and system concepts)
- Quantities fielded
- Location on production learning curve

4.0 Support Cost

Enter the most accurate numerical values available for each of the support cost parameters listed and identify each as to Life Cycle Cost Model Input or Actual Cost Input.

4.1 Initial and pipeline spares

4.2 Replacement spares

4.3 On-equipment maintenance

4.4 Off-equipment maintenance

4.5 Inventory entry and supply management

4.6 Support equipment

4.7 Personnel training and training equipment

4.8 Technical data and documentation

4.9 Logistics management

5.0 Support Factors

5.1 Applicable Maintenance & Echelons: Indicate the skill requirement for maintenance personnel at the site (organizational), at the shop, (intermediate) and at the depot facility. Skill level classifications may be expected to vary with the organization responsible for equipment maintenance.

Indicate the number of maintenance personnel assigned to the site (organizational) shop (intermediate) or the depot locations.

Indicate the level of sparing at each location.

5.2 Repair Strategy: Indicate repair philosophy for line replaceable (LRU) or shop replaceable (SRU) units.

- Throwaway - LRUs/SRUs are thrown away instead of repaired
- Intermediate - LRUsSRUs are repaired at the equipment site
- Depot - LRUs/SRUs are sent to a central repair shop (depot) for repair

5.3 Site Maintenance Level: Indicate the functional level(s) at which on-site personnel have maintenance capability(ies)

- LRU
- SRU
- Part

EXAMPLE

AN/ARC-164

FINANCIAL AND SUPPORT DATA SUMMARY FORM

FINANCIAL AND SUPPORT DATA SUMMARY FORM

Nomenclature UHF Radio Set

Identification No. ______ Contract No. F33657-74-0545

Source Document Acces. No. ______ ______ ______ ______

Type AN/ARC-164

ACQUISITION COST

	ESTIMATED/PROPOSED	ACTUALS
R&D cost		
Test & Evaluation Cost		
Non-Recurring Production Cost		
Recurring Production Cost		
Quantity Procurred	10,000	

ACQUISITION FACTORS (Subsume)

3 Competing Development Contracts Between Collins, RCA and Magnavox.

SUPPORT COST

	LCC MODEL INPUTS	ACTUALS
Initial and Pipeline Spares		
Replacement Spares		
On-Equipment Maintenance		
Off-Equipment Maintenance		
Inventory Entry and Supply Management		
Support Equipment		
Personnel Training and Training Equipment		
Technical Data and Documentation		
Logistics Management		

SUPPORT FACTORS

APPLICABLE MAINTENANCE & ECHELONS		SKILL LEVEL	NO. OF PERSONNEL	LOWEST LRU/SRU SPARING
Organization (Field)	☒	5	1	☒
Intermediate (Shop)	☒			☐
Depot/Plant	☒			☐

LRU/SRU REPAIR STRATEGY		SITE MAINTENANCE LEVEL	
Throw Away	☐	LRU	☒
Intermediate Repair	☒	SRU	☐
Depot Repair	☒	Part	☐

PROCEDURE FOR RELIABILITY DATA SUMMARY FORM

1.0 System, Subsystem and Equipment Description

Enter appropriate information in the space provided.

1.1 Nomenclature: Record the official name of the equipment, to which this data entry applies and all applicable higher order assembly levels.

1.2 Type: Normally this will be a combination of letters and numerals arranged in a specific sequence providing a short significant method of identification. (Reference MIL-STD-196)

1.3 Data Date: Record the date of the document containing the most current data.

1.4 Contract Number: Self explanatory

1.5 Source Document Accession Numbers: Self explanatory

2.0 Reliability Numeric

Enter the applicable MTBF numeric

3.0 Program Phase

Indicate the program phase to which this data entry is applicable.

- Development
- Production
- Operation

4.0 Reliability Parameter

Indicate if the reliability numeric is a functional MTBF or a Series (Logistics) MTBF.

5.0 Data Source

Indicate the source of this reliability numeric data. The applicable sources include:

- Contract or Specification Requirement
- Allocation
- Analysis and Prediction Report
- Demonstration Test Report
- Production Sampling Verification Test Report

- SEDS Data and Operating Time
- 66-1 Data and Flight Time
- 66-1 Data and Actual Operating Time
- Other (explain)

6.0 Data Level

Indicate the hardware level to which this data is applicable.

- System
- Subsystem
- Set
- Functional Group
- Unit or Component

7.0 Failure Data

Enter the applicable number of failures both relevant and nonrelevant and the number of hours both operating and non-operating.

8.0 Remarks

Enter any additional data and background information that may be of interest and that are specifically applicable to this data item entry.

9.0 Example

Figure 4.3-8 is an example of what a completed Reliability Data Summary Form may look like.

EXAMPLE

AN/ARC-164

RELIABILITY DATA SUMMARY FORM

RELIABILITY DATA SUMMARY FORM

	NOMENCLATURE	TYPE
System Identification		
Subsystem Identification		
Equipment Identification	UHF Radio Set	AN/ARC-164

Data Date 1-2-74 Contract No. F33657-73-C-0192

Source Document Accession No. 10267

R Numeric 181.8 hours

PROGRAM PHASE

- Development ☒
- Production ☐
- Operational ☐

RELIABILITY PARAMETER

- Series (Logistics) MTBF ☒
- Functional MTBF ☐
- MTBM ☐

DATA SOURCE

- Contract/Specification Req't ☐
- Allocation ☐
- Analysis and Prediction Report ☐
- Demonstration Test Report ☒
- Production Sampling Verification Test Report ☐
- SEDS Data and Operating Time ☐
- 66-1 Data and Flight Time ☐
- 66-1 Data and Actual Operating Time ☐
- Other (explain) ☐

REMARKS ☐ (subsume)

DATA LEVEL

- System ☐
- Subsystem ☒
- Equipment ☐

Failures ______

Operating hours 4,000

Non-Operating hours ______

Failures Relevant 22

Failures Non-Relevant 8

PROCEDURE FOR
MAINTAINABILITY DATA SUMMARY FORM

1.0 System, Subsystem and Equipment Description

Enter appropriate information in the space provided.

1.1 Nomenclature: Record the official name of the equipment to which this data entry applies and all applicable higher order assembly levels.

1.2 Type: Normally this will be a combination of letters and numerals arranged in a specific sequence providing a short significant method of identification. (Reference MIL-STD-196)

1.3 Data Date: Record the date of the document containing the most current data.

1.4 Contract Number: Self explanatory

1.5 Source Document Accession Numbers: Self explanatory

2.0 Data Type

Indicate the type of data being entered. The applicable data types include:

- Specified or Apportioned
- Predicted
- Demonstrated
- Flight or Field Test
- Operational

3.0 Maintainability Parameter

Note the specific type of maintainability parameters being recorded. The applicable types of maintainability parameters are:

- MTTR
- M_{ct}
- M_{max} *(at either 90% or 95% confidence level)*
- M_{pt}

- MMH/Flight hr/Operating hr
- Mean Down Time
- BIT Effectiveness

For MTTR, M_{ct} and M_{max} also note if the parameter applies to organizational or intermediate level maintenance.

4.0 Program Phase

Identify the equipment life cycle to which the specific data item applies.

- Development
- Production
- Operation

5.0 Maintainability Numeric

Enter the numeric value of this maintainability data item.

6.0 BIT Effectiveness

If BIT Effectiveness was checked under Maintainability Parameter (see paragraph 3.0 above) then complete the field entitled BIT EFFECTIVENESS.

This is a measure of the effectiveness of the Built-In Test (BIT) capability incorporated within the equipment. It is concerned with both the capability of the equipment to detect a failure or failures within itself and/or associated equipments and also the ability to subsequently locate and identify the specific hardware item responsible for the detected malfunction.

On Line/Automatic refers to that capability available without operator intervention or assistance. A periodic automatically initiated self test mode would be an example of this capability. Off Line/Initiated refers to that capability which may be available through the intervention or assistance of the operator. Manual switching the equipment into a self test operating mode or initiating additional diagnostic tape controlled sequences would be examples of off line/initiated capability.

The fault detection function is concerned with both the BIT's ability to identify faults when they occur and also its ability to prevent indicating failures when they indeed do not exist; i.e., false alarms.

Fault isolation is frequently defined in two or more tiers allowing progressively higher percentage of faults to be isolated to progressively larger groups of equipment items. For example: a) 50% of all faults isolate to 1 LRU, b) 75% of all faults to 2 or less LRU's, c) 95% of all faults isolated 3 or less LRU's.

Indicate the fault detection capability of the BIT and the applicable false alarm rate. Also indicate the capability of the BIT to fault isolation to a single LRU/SRU and also to multiple LRU/SRUs. Differentiation should be noted for both fault isolation and fault detection if these are applicable to on line/automatic operation or to off line/initiated operation of the BIT.

EXAMPLE

AN/ARC-164

MAINTAINABILITY DATA

SUMMARY FORM

MAINTAINABILITY DATA SUMMARY FORM

NOMENCLATURE

System Identification ______________________ ______________

Subsystem Identification ______________________ ______________

Equipment Identification UHF Radio Set AN/ARC-164

Data Date 1-2-74 Contract No. F33657-73-C-0192

Source Document Accession No. 10267

MAINTAINABILITY PARAMETER

DATA TYPE			Organization	Intermediate
Specified/apportioned	☐	MTTR (M_{CT})	☒	☐
Predicted	☐	M_{Max} (95%)	☐	☐
Demonstrated	☒	M_{Max} (90%)	☐	☐
Flight/Field Test	☐	M_{PT}	☐	
Operational	☐	MMH/FH/Operating Hr	☐	
		Mean Down Time	☐	
		BIT Effectiveness	☐	

PROGRAM PHASE

Development ☒

Production ☐ M Numeric 7.3 Minutes

Operational ☐

BIT EFFECTIVENESS

	ON LINE/AUTOMATIC	OFF LINE/INITIATED
FAULT DETECTION		
Capability	____%	____%
False Alarms	____%	____%
FAULT ISOLATION		
to (1) LRU/SRU	____%	____%
to ____ or less LRU/SRUs	____%	____%

PROCEDURE FOR R&M PROGRAM EFFECTIVENESS FORM

1.0 System Description

Enter the appropriate information in the space provided.

1.1 Nomenclature: Record the official name of the contracted equipment.

1.2 Type: Normally this will be a combination of letters and numerals arranged in a specific sequence providing a short significant method of identification.

1.3 Contractor: Self explanatory

1.4 Contract Number: Self explanatory

1.5 Procurring Agency: Self explanatory

1.6 Using Command: Self explanatory

1.7 Data Date: Record the date of the document containing the earliest data and also the date of the document containing the most current data.

1.8 Source Document Accession Numbers: Self explanatory

2.0 Evaluation Criteria

Score each of the evaluation criterion using the results from the questionnaires submitted by each of the qualified observers. (For additional information regarding the observers questionnaire and scoring details see appendix.)

The individual criterion are:

2.1 Percentage of original R&M program requirements completed in their entirety.

2.2 Percentage of R&M items subsequently eliminated or reduced due to dollar or schedule constraints.

2.3 Increasing, decreasing, or consistent attention to the R&M requirements.

2.4 Management changes involving either the contractor or the procuring agency and their effect on the R&M program.

2.5 Attitude of contractor and procuring agency regarding the R&M requirements.

2.6 Major program changes during the program such as a significant reduction in the number of items to be procured, program stretchouts, mission definition changes, etc.

2.7 R&M requirement and changes resulting from program changes.

2.8 Number of major ECPs/design changes occurring as a result of R&M deficiencies uncovered during:

a. Manufacturing

b. Contractor's tests

c. Demonstration tests

d. Field deployment

2.9 Number of major problem areas uncovered during the PDR/CDR

2.10 Percentage of those resolved in a timely manner to the satisfaction of both the contractor and the procuring agency.

2.11 Percentage of cost overruns on the program.

2.12 Percentage of cost overruns attributed to R/M deficiencies.

<u>3.0 Summation</u>

Calculate the total program effectiveness score using the individual criterion scores and their appropriate weighting factors.

<u>4.0 R&M Effectiveness Determination</u>

Determine the relative R&M Effectiveness as follows:

High R&M Program Effectivity $>$ 90

Medium R&M Program Effectivity 50 - 90

Low R&M Program Effectivity $<$ 50

APPENDIX D

SUMMARY OF SYSTEMS AND DESCRIPTION OF EACH

SYSTEMS/ EQUIPMENT IDENTIFICATION	DESCRIPTION
AN/TSC 60(V)	Communication Central (large complex system)
MAU 169/B	Laser Guided Bomb (Relatively simple system)
RASSAR	Radar (Test bed development model only)
AN/GSC-24	Multiplexer 1 or 2 drawers, 31 card types
AN/GSC-171	Ground Communication System (small item, 1 box)
AN/ARC-162	VHF Radio (loosing competitor to ARC-164
TACC	Air Control Communication System (large complex system)
AN/TPX-42A	Beacon Radar (7 nomenclatured items)
AN/ARN-101	TALONS Navigation Set (10 nomenclatured items)
AN/ARC-163	VHF Radio (loosing competitor to ARC-164)
AN/ARC-164	VHF Radio (single Box, 30 subassemblies)
AN/ALQ-94	ECM Device (4 boxes, 67 subassemblies, includes RAT test)
LORAN D	Navigational System
SPN/GEANS	Position Navigational System (2 nomenclatured boxes, 31 cards)

SYSTEMS/ EQUIPMENT IDENTIFICATION	DESCRIPTION
AN/USM-430	Electronic System Test Set (2 nomenclatured boxes, 50 cards)
EAR	Electronic Agile Radar
AWACS	Airbourne Surveillance Radar (very large complex system)
FREQ DIV Mult. Set	ACP Internal Communications
AN/FPS-108	Cobra Dane Radar (large complex system)
TACAN AN/TRN-41	(3 boxes, 13 modules)
AN/USC-26	Data Modem (single box, 30 subassemblies)
AN/TPS-43	Transportable Radar
AN/TPS-44	Transportable Radar
AN/TPS-48	Transportable Radar
AN/PRC-41	Portable Radio
AN/PCR-47	Portable Radio
AN/TRC-87	Portable Radio
AN/MRC-108	Mobile Radio

SYSTEMS/ EQUIPMENT IDENTIFICATION	DESCRIPTION
AN/TGC-26	Transportable Ground Communication
AN/TSQ-91(V)	Transportable Test Set
AN/TSQ-92(V)	Transportable Test Set
AN/TSQ-93(V)	Transportable Test Set
AN/TTC-30	Transportable Telephone Terminal
AN/GYQ-18	Satellite Tracking Set
AN/GPA-125	Ground Fixed Radar
AN/MCC-012	Mobile Communications System
AN/GYQ-15	Ground Fixed Data Processing Equipment
AN/GYQ-17	Ground Fixed Data Processing Equipment
AN/GKC-01	Tracking Equipment
AN/GIC-21	Ground Fixed Telecommunications
AN/GSQ-175	Equipment Test Set
AN/GSC-28	Ground Fixed Communication Set

SYSTEMS/ EQUIPMENT IDENTIFICATION	DESCRIPTION
AN/GYK-21	Ground Fixed Data Processing
AN/APG-63	Radar Set
AN/ASK-6	Air Data Computer
AN/ASW-38	Flight Control Computer
CP-1070/AYK	Digital Computer
OA-8638/ARD	Direction Finder Group
AN/ASN-10 AN/ASN-108	Attitude Heading Referance Set
AN/AVQ-20	Heads Up Display
MX-9278 A	Navigation Group
AN/TGC-27	Portable Ground Communications
AN/ALQ-417	Airborne Communications
AN/ALQ-109	Airborne Communications
AN/GRC-106	Ground Radio Communications
An/ALQ-128	Airborne Counter Measures

SYSTEMS/ EQUIPMENT IDENTIFICATION	DESCRIPTION
AN/ASW-38	Flight Control Computer
P-1070/AYK	Digital Computer
OA-8638/ARD	Direction Finder Group
AN/ASN-108	Attitude Heading Referance Set
AN/AVQ-20	Heads Up Display

MISSION
of
Rome Air Development Center

RADC plans and conducts research, exploratory and advanced development programs in command, control, and communications (C^3) activities, and in the C^3 areas of information sciences and intelligence. The principal technical mission areas are communications, electromagnetic guidance and control, surveillance of ground and aerospace objects, intelligence data collection and handling, information system technology, ionospheric propagation, solid state sciences, microwave physics and electronic reliability, maintainability and compatibility.